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critically ill well assessed

evaluation of the rapid response system in a university medical center

ISBN 978.94.625.9256.8

Publication of this thesis was financially supported by:
- HAN University of Applied Science, Nijmegen NL
- Radboud University, Medical Centre, Nijmegen NL
- Doczero E-learning voor professionals in de gezondheidszorg & ambulancezorg NL

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CRITICALLY ILL, WELL ASSESSED

EVALUATION OF THE RAPID RESPONSE SYSTEM
IN A UNIVERSITY MEDICAL CENTER

PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus prof. mr. S.C.J.J. Kortmann,
volgens besluit van het college van decanen
in het openbaar te verdedigen
op vrijdag 26 september 2014
om 10.30 uur precies

door

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geboren op 7 april 1952
te Noordoostelijke Polder

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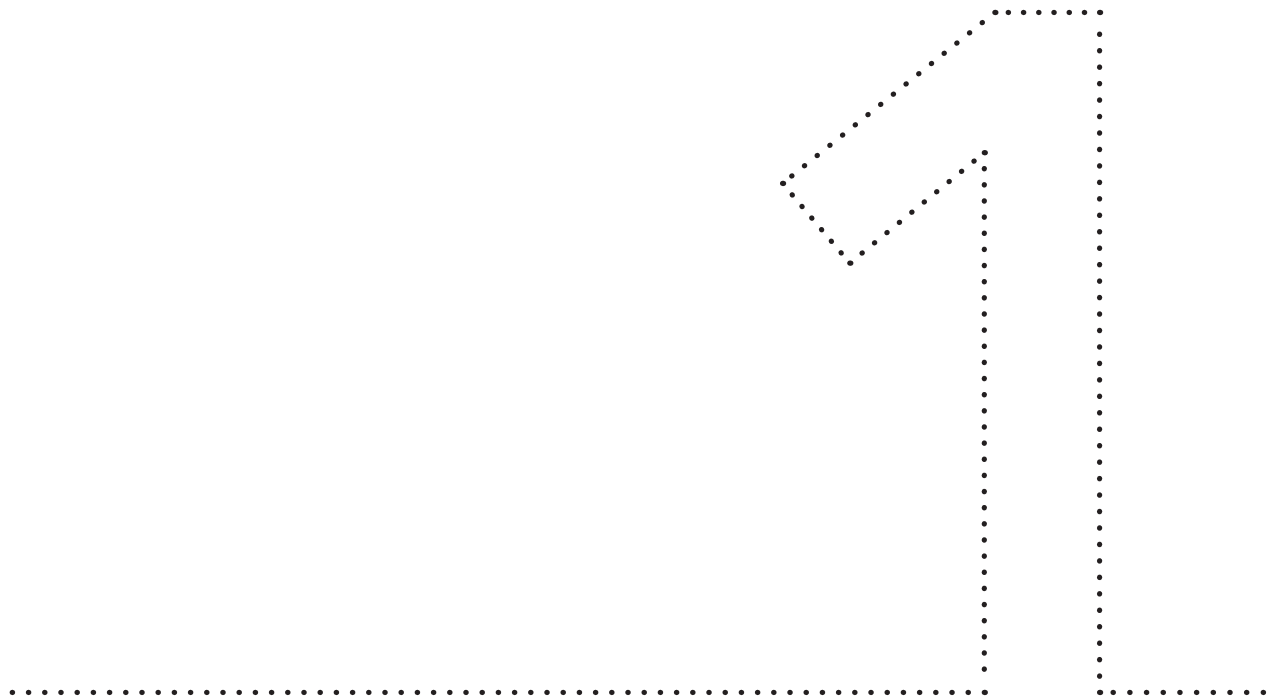
'… not that the habit of ready and correct observation will by itself make us useful nurses, but that without it we shall be useless with all our devotion.'

Florence Nightingale 1898: Notes on nursing What it is, and What it is Not.

Contents

General introduction



Introduction

Hospital care is becoming complex and specialized, increasing the opportunity for errors. Already in 1991 two large studies in the United States showed that approximately 3 percent of all hospital patients experienced an adverse event of which half could have been prevented. Subsequent studies in the United States and other countries were in line with these findings[1]. A study in the Netherlands showed that 5.7 percent of the hospital patients suffered from an adverse event and 2.3 percent of these events were possibly due to an error of the hospital staff[2].

The Institute for Healthcare Improvement (IHI), a not-for-profit organization and leading innovator in health and health care improvement worldwide, launched the 100, 000 lives campaign in 2004 and the subsequent 5 million lives campaign in 2006[3]. These campaigns aim to make healthcare safer and more effective by introducing best practices across hospitals and other healthcare institutions in the United States. This initiative also inspired the development of safety campaigns in many other countries around the world. In the Netherlands a nationwide hospital patient safety program was launched in 2008. The program includes 10 main topics based on a study of adverse events in Dutch hospitals and on international consensus on important topics of patient safety[4]. One of these topics is the implementation of a rapid response system for prompt identification and treatment of critically ill hospital patients[5].

The critically ill patient

A patient is considered critically ill when one or more vital functions, e.g. airway, breathing, circulation, or neurological functions are instable and potentially life-threatening. Studies have established that most patients experience physiologic instability from 1 to 48 hours prior to an adverse event[6-9]. Respiratory distress[6,7,10-13] low oxygen saturation[13-15] and a lower consciousness level[6,7,12,14] are the most frequently found predictors for an adverse event. Patients are more likely to develop an adverse event when multiple vital functions are deteriorating[7,11,16,17] or when they experience multiple episodes of deterioration[6,11]. Unstable vital functions are often not recognized and are treated inadequately by the ward staff[7,18].

Rapid response systems

Rapid response systems (RRS) were introduced based on the concept that if unstable vital functions are timely identified and corrected, patient's outcome may improve. The RRS comprises of an afferent- and an efferent limb. Evaluation and feedback and resource allocation to facilitate the system are also essential components (Figure 1)[19].

- **The afferent limb**

The afferent limb of the RRS includes detection of critically ill patients and triggering for adequate help. To detect a critically ill patient in a timely matter, a variety of physiological track and trigger systems have been developed. The track and trigger system should be used for periodic observations of selected basic vital functions (the 'tracking') with predetermined criteria (the 'trigger') for activating adequate help[20].

Track- and trigger systems can be classified as single-and multiple parameter systems. Single parameter systems consist of a set of trigger criteria with predefined thresholds. One abnormal criterion is enough to active the system[21]. Multiple-parameter systems involve an aggregate weighted scoring system. Weighted scores are assigned to each physiological value. The sum of these individual scores triggers the system if a predefined threshold is reached[20,22].

There is no consensus about the ideal track and trigger system since most studies on abnormal vital functions were retrospective, with lots of missing values, including in particular respiratory rate, oxygen saturation, consciousness level and urine production[23-25]. Furthermore, in most studies denominator data, e.g. the actual number of deviating vital functions in all patients, including patients who did not develop an adverse event, were missing[23,24]. There is consensus that at least oxygen saturation, respiratory rate, heart rate, blood pressure, temperature and level of consciousness should be monitored regularly. Additional variables to be considered under certain circumstances include: airway patency, changes in behavior, capillary refill time, urine output, basic biochemistry and hematology results. There is no appropriate standard for the frequency of monitoring. There is consensus that periodic observation of the vital functions should be executed at least every 12 hours, but observations every 6 hours are considered preferable[23]. Automated systems for collecting and processing patients' vital signs have been developed recently[26]. Oxygen saturation, heart frequency and blood pressure are automatically assessed. Respiratory rate and consciousness level should be manually entered by the staff. These systems enable more intensive monitoring of patients when needed.

In most countries, triggering of specialized teams can be done by any personnel on the ward[19]. In the Netherlands, a two-tiered triggering protocol is recommended[5]. In the first tier, nurses have to call the ward physician immediately if triggering criteria are met. In the second tier the ward physician activates the specialized team immediately if a serious situation exists or if the patient does not stabilize after an initial intervention. Nurses are expected to trigger the specialized teams directly in case the ward physician does not comply with the protocol or is unavailable.

- **The efferent limb**

The efferent limb includes the assessment of the patient by a specialized team, preferably available 24 hours a day/7 days a week. These specialized teams should be able to make a proper diagnosis, initiate therapy, and rapidly triage the patient to a higher level of care. Composition of the specialized teams varies between a physician led medical emergency team (MET) and a nurse-led critical care outreach team (CCO)[19]. In the Netherlands physician led teams are recommended[5].

- **Administration**

Thorough documentation is essential for evaluation of the team activations or preventable adverse events for which the team was not activated[19]. This can be used to improve hospital processes. Furthermore, formal overall governance for the planning, implementation, and maintenance of the RRSs are necessary to provide continuity.

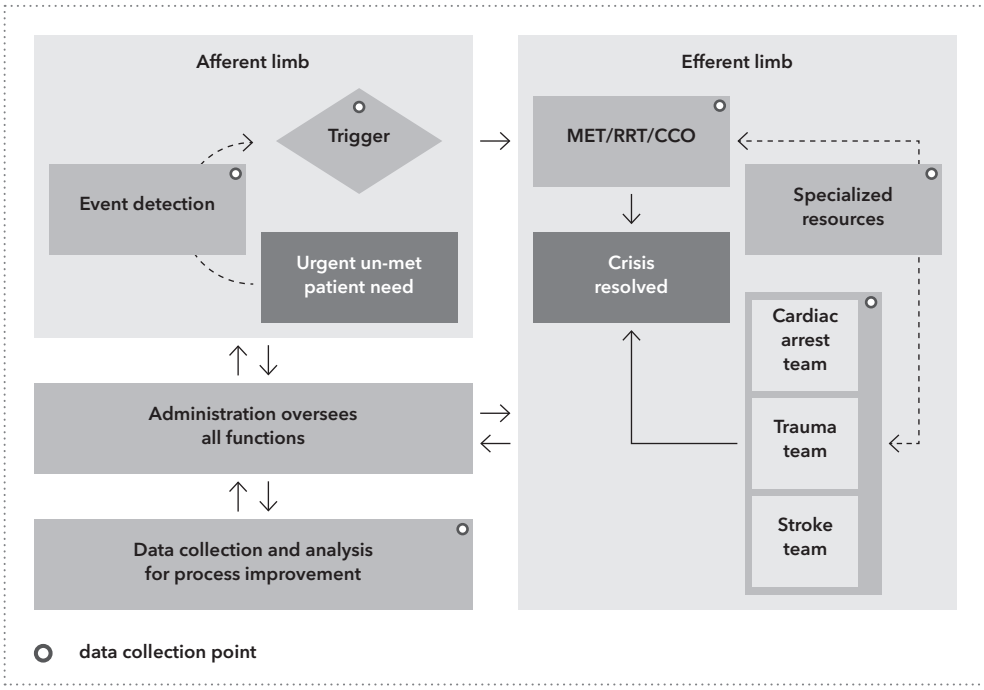


Figure 1 **The rapid response system structure** [20]

Effectiveness of an RRS

Although the effectiveness of an RRS appears to be self-evident, it is not unequivocally proven by a decline in serious adverse events[27-32]. Effectiveness of an RRS has been studied most often in single-centers with the use of a historical-controled study design. These studies suggest benefits from an RRS on serious adverse events such as (unexpected) deaths, cardiac arrest rate and (un)planned ICU admissions (from wards)[7,33-39]. However, these studies poorly controlled for secular trends, if at all. Only two cluster randomized controlled trials were executed. In a single-centre study[40] the authors showed a reduction in hospital mortality but the MERIT multi-centre study[41] showed no effects on the composite outcome of incidence of cardiac arrests, unexpected deaths and unplanned ICU admissions from wards.

In several studies the authors suggested that the effectiveness of the RRS was underestimated due to underutilization of the response team. For example, in the MERIT study in only 30 percent of the events where patients satisfied triggering criteria, a response team was activated. An ineffective implementation strategy was one of the proposed explanations[33,34,41].

Implementation strategy

Implementation strategies in studies on the effectiveness of an RRS consisted of informing or educating the ward staff about the trigger criteria and calling procedure of the response team[7,33,34,41], placement of posters[7,34-36], handing out laminated cards to the ward staff[34], communication with ward staff members in case the calling protocol was not followed up[38] and debriefing the ward staff in particular events after triggering the response team[34]. Authors gave no further information about the content, duration or frequency of the information- or education program. Continued education[33,34,41] and the use of a more sophisticated, broad based implementation strategy including the use of key leaders, regular feedback etc.[41] are suggested interventions to enhance the effectiveness of the RRS. The effects of the proposed implementation strategies on the effectiveness of an RRS are not studied yet.

Health related quality of life

Although prevention of serious adverse events is the primary goal of the RRS, the system may also have an impact on health related quality of life (HRQOL). HRQOL is clinically relevant and contribute to a better understanding of healthcare expenditure and resource utilization in patient care[42]. However, until now no studies investigated the effects of an RRS on HRQOL.

To estimate the HRQOL numerous instruments have been developed which can be divided in generic and specific instruments. Generic HRQOL instruments are applicable across a wide range of populations for a wide range of conditions or diseases whereas specific instruments are developed to assess the HRQOL in populations with a particular condition or disease. Since surgical ward patients differ in condition and disease, a generic HRQOL instrument will be needed to measure the effects of an RRS on HRQOL. Generic HRQOL outcomes can be expressed in a health profile and in a preference based index. Health profiles represent outcomes on the different dimensions of health status. The preference based index provides a single number on a continuum from perfect health (usually 1) to death (0) or even worse than death (minus 0)[42]. HRQOL can be studied between people (discriminative instrument) and over time (evaluative instrument)[43]. HRQOL should be studied over time to estimate the effects of an RRS.

Health care costs

Recent years have seen an explosion in health care costs. An average Dutch family nowadays spends nearly a quarter of their income on health care costs. If the health care costs continue

to grow as they did over the past 10 years, costs can add up to 50% of the income within another 10 years[44]. The growth in health care costs makes decisions, based on cost-analysis essential.

It is hypothesized that the RRS is cost saving[19,45]. However, until now no studies investigated the impact of an RRS on hospital costs. Three main methods are available to assess the economics of an RRS: the cost-benefit-, the cost-effectiveness-, and the cost-utility analysis[46]. The cost-benefit analysis lists all the costs and benefits that might result from an RRS. Costs and benefits must be expressed in monetary terms. Expected benefits of an RRS are a reduction in unplanned ICU admissions and in hospital length of stay, which are easy to express in monetary terms. However, quantifying a saved life in monetary terms is difficult. The cost-effectiveness analysis expresses the net direct and indirect costs and cost savings in terms of a predefined unit of health outcome, e.g. a saved (or lost) life. In a cost-utility analysis the predefined unit of health outcome is the quality-adjusted life year (QALY). This outcome can be calculated from the HRQOL preference based index.

Aim of this thesis

The aim of this thesis is to gain insight in the effect of an RRS on serious adverse events. In addition, we studied the effect of a multifaceted implementation strategy on adherence of the ward staff to the afferent procedure. Furthermore, we assessed the effects of an RRS on HRQOL and on hospital costs.

Outline of this thesis

Chapter 2 describes the effects of the RRS on serious adverse events, i.e. cardiac arrests, unexpected deaths and unplanned ICU admissions in patients undergoing major surgery. **Chapter 3** focuses on the multifaceted implementation of an RRS and the adherence of the ward staff to the afferent procedure. **Chapter 4** describes the effects of an RRS on HRQOL. We measured HRQOL presurgery and at 3 and 6 months following surgery. In **Chapter 5** the hospital costs of an RRS are explored. In addition, we executed scenario analyses to test our hypothesis that costs for unplanned ICU admissions may be reduced when patients are referred to the ICU with a lower disease severity. In **Chapter 6** we discuss the reasons why it is so difficult to show the effectiveness of an RRS. We focus on study designs and the chosen outcome measures. Finally, in **Chapter 7** we summarize and discuss our study results, followed by the main conclusion. We end this chapter with the implications for clinical practice and future research.

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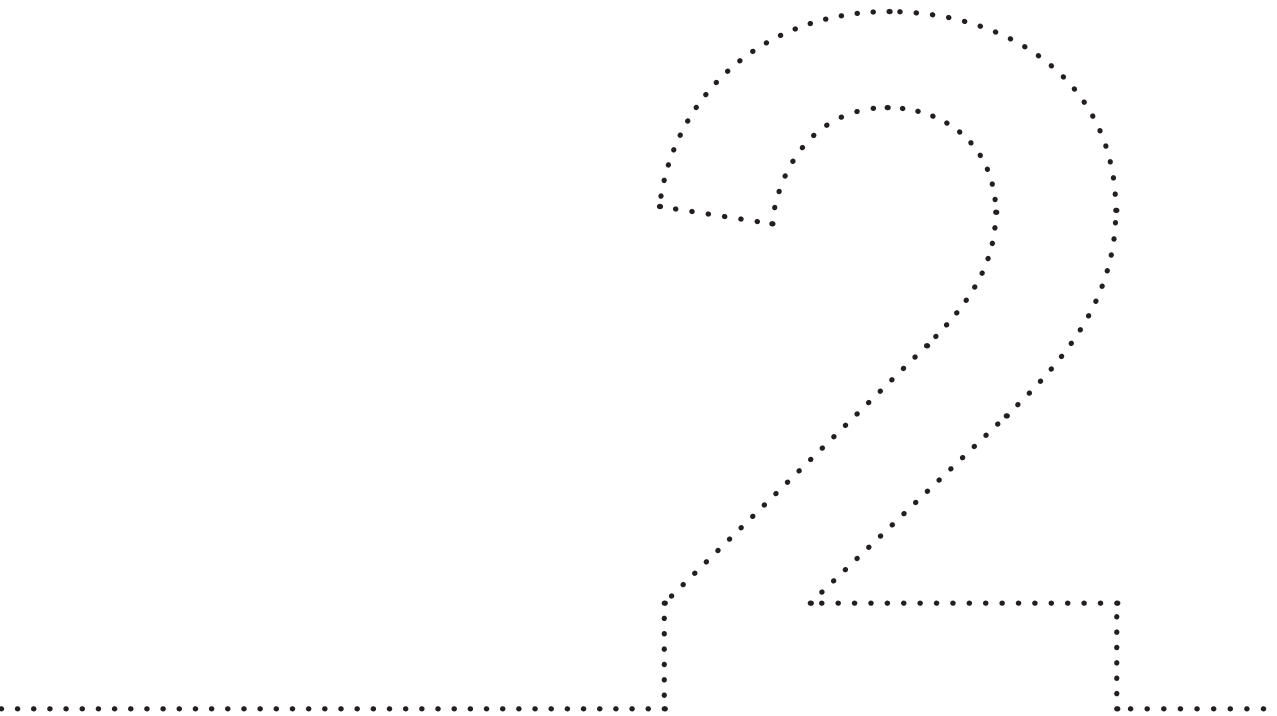
Incidence of cardiac arrests and unexpected deaths in surgical patients before and after implementation of a rapid response system



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Annals of Intensive Care 2012; 2 (1) 20-26

Abstract

Background

Rapid response systems (RRSs) are considered an important tool for improving patient safety. We studied the effect of an RRS on the incidence of cardiac arrests and unexpected deaths.

Methods

Retrospective before–after study in a university medical center. We included 1,376 surgical patients before (period 1) and 2,410 patients after introduction of the RRS (period 2). Outcome measures were corrected for the baseline covariates age, gender, and the American Society of Anesthesiologists (ASA) classification.

Results

The number of patients who experienced a cardiac arrest and/or who died unexpectedly decreased nonsignificantly from 0.5% (7/1,376) during period 1 to 0.25% (6/2,410) during period 2 (odds ratio (OR) 0.43; 95% confidence interval (CI) 0.14-1.3). The individual number of cardiac arrests decreased nonsignificantly from 0.29% (4/1,367) to 0.12% (3/2,410; OR 0.38; 95% CI 0.09-1.73) and the number of unexpected deaths decreased nonsignificantly from 0.36% (5/1,376) to 0.17% (4/2,410; OR 0.42; 95% CI 0.11-1.59). In contrast, the number of unplanned intensive care unit (ICU) admissions increased from 2.47% (34/1,376) during period 1 to 4.15% (100/2,400) during period 2 (OR 1.66; 95% CI 1.07-2.55). Median acute physiological assessment and chronic health evaluation (APACHE) II score at unplanned ICU admissions was 16 in period 1 versus 16 in period 2 (not significant [NS]). *Adherence to RRS procedures*. Observed abnormal early warning scores ≤72 h preceding a cardiac arrest, unexpected death, or unplanned ICU admission increased from 65% (24/37 events) in period 1 to 91% (91/101 events) in period 2 ($p < 0.001$). Related ward physician interventions increased from 38% (9/24 events) to 87% (79/91 events; $p < 0.001$). In period 2, ward physicians activated the medical emergency team in 65% of the events (59/91), although in 16% (15/91 events) activation was delayed for 1 or 2 days. The overall medical emergency team dose was 56/1,000 admissions.

Conclusions

Introduction of an RRS resulted in a 50% reduction in cardiac arrest rates and/or unexpected death. However, this decrease was not statistically significant partly due to the low baseline incidence. Moreover, delayed activation due to the two-tiered medical emergency team activation procedure and suboptimal adherence of the ward staff to the RRS procedures may have further abated the positive results.

Introduction

Hospitalized patients often show deteriorating vital signs up to 48 h before unexpected death and other serious adverse events[1]. To improve timely recognition and treatment, rapid response systems (RRS) have been introduced. An RRS includes a set of predetermined clinical criteria for assessing patients on a general ward, preferentially at a minimum interval of 12 h[2]. After meeting predefined criteria, a rapid response team has to be activated. This team will evaluate the patient's physical condition and initiate treatment[3]. RRSs are considered an important tool for improving patient safety and consequently have been implemented and studied worldwide[4,5]. However, great heterogeneity of systems exists concerning the used track and trigger method, the composition of the rapid response team, the rapid response team escalation protocol, and rapid response team interventions. Furthermore, although the usefulness of an RRS appears to be self-evident, research into its effectiveness has yielded equivocal results[6-11]. Despite the presence of an RRS, late rapid response team activation regularly occurs[12-15], suggesting suboptimal adherence of the ward staff with the RRS system. The purpose of the current study was to estimate the effects of an RRS, including a two-tiered medical emergency team (MET) calling procedure, on the incidence of cardiac arrests and unexpected deaths in surgical patients and to study the adherence of the staff to the RRS procedures.

Methods

We conducted a retrospective before–after study of surgical patients in a university hospital. The before study was conducted from January 2006 until December 2006 and the after study from April 2007 until April 2009. Patients who were still admitted at the end of the study periods were followed until discharge from the surgical ward. The need for informed consent was waived by the Medical Ethics Committee of district Arnhem-Nijmegen, CMO-nr.: 2005/310.

Inclusion criteria

We included all patients who stayed in the surgical ward for ≥72 h following general surgery, including central or extensive peripheral vascular surgery, major oncologic surgery, lung surgery, extensive abdominal surgery, and trauma.

RRS implementation

The RRS included the introduction of a MET and the use of a single-parameter track and trigger system. The system was based on the following early warning scores (EWS): respiratory rate <8 or >30 per minute, oxygen saturation <90%, systolic blood pressure <90 or >200 mmHg, heart rate <40 or >130 per minute, a decrease of two points in the eye, motor, verbal (EMV) score or if the nurse felt worried about the patient's condition[16]. The RRS included a two-tiered MET calling protocol. In the first tier, nurses had to call the ward physician immediately if one of the EWS criteria was met. The ward physician had to evaluate the patient at the bedside within 10 min. In the second tier, the ward physicians activated the MET immediately if a serious situation existed or if the patient did not stabilize after an initial intervention. The MET was a physician-led team, including a critical care physician and a critical care nurse, and was accessible 24/7. If the ward physician was unable to visit the patient in time, nurses were expected to activate the MET directly. Ward physicians were junior doctors, present in the hospital 24/7. In case of a cardiac arrest, the cardiac arrest team was called.

During the RRS implementation period, medical and nursing staff were informed about the system. A 1-day education program was mandatory for the nursing staff and optional for the medical staff.

Individual pocket-sized, laminated cards displaying the EWS, the SBAR (situation, background, assessment, and recommendation) communication protocol, and the MET beeper number were given to the ward nurses and doctors. Posters with the EWS

and the MET beeper number also were displayed in the wards. During the intervention period, newsletters were sent to the medical and nursing staff with feedback on the EWS observation- and ward physician/MET activation rates.

Measurements

The health status of patients in period 1 and period 2 was compared using the American Society of Anesthesiologists (ASA) classification, a system for assessing the physical status of patients, before surgery[17].

Primary outcomes

Primary outcome was the number of patients who experienced a cardiac arrest and/or unexpectedly died. Unexpected death was defined as death in the surgical ward or death in the intensive care unit (ICU) after an unplanned ICU admission.

Secondary outcomes

Secondary outcomes were the number of unplanned ICU admissions, the acute physiological assessment and chronic health evaluation (APACHE II) scores, and ICU length of stay (LOS) in patients with an unplanned ICU admission. An unplanned ICU admission was defined as an unexpected ICU admission from the ward, with or without a preceding emergency reoperation. APACHE II scores were estimated within 24 h after unplanned ICU admissions and defined as APACHE II scores at unplanned ICU admission. In addition, we studied the number of deaths with a do not resuscitate (DNR) order.

Adherence to RRS procedures

Adherence of nurses and doctors was defined as the number of documented abnormal EWS that led to one or more ward physician interventions and to one or more MET interventions. A MET intervention was defined as delayed when at least one abnormal EWS was documented for 1 or 2 days preceding the first MET consult. The overall MET dose was defined as the number of MET interventions per 1,000 admissions[18].

Data collection

Data on age, gender, unplanned ICU admissions, APACHE II scores, mortality, and unplanned ICU LOS were obtained from the electronic hospital database. Cardiac arrests were retrieved from the cardiac arrest registration database. Subsequently, the recorded EWS, ward physician, and MET interventions were collected from the medical records of

patients who had a serious adverse event (SAE). An SAE was defined as a cardiac arrest, an unexpected death, or an unplanned ICU admission. For this, the medical records of the patients were independently reviewed by two researchers. Although the EWS was not used before implementation of the RRS, documented vital signs and related ward physician interventions were collected according to the EWS criteria. If patients had an emergency reoperation before the unplanned ICU admission, data on EWS preceding the emergency reoperation were collected. Data collection started within 72 h preceding the SAE.

Statistical methods

Data were analyzed with SPSS, version 17. Comparisons between period 1 and 2 were made using chi-square tests for categorical data, Student's *t* test for normally distributed data and the Mann-Whitney *U* test for nonnormally distributed data. We also performed a logistic regression analysis in which we adjusted the primary and secondary outcomes for the baseline covariates age, gender, and ASA score. $P < 0.05$ was considered statistically significant.

Results

Characteristics of the study population

The two groups differed significantly in age, gender, and ASA score (Table 1). In period 1, 2.2% (34/1,376) of the patients experienced 43 serious adverse events (SAEs), including cardiac arrest, unexpected death, or unplanned ICU admission, in period 2, 3.8% (91/2,410) of the patients experienced 107 SAEs. Characteristics of the SAE patients did not differ significantly between the periods (Table 2).

Primary outcomes

The percentage of patients who experienced a cardiac arrest and/or who unexpectedly died was 0.5% (7/1,376) in period 1 versus 0.25% (6/2,410) in period 2 (odds ratio (OR) 0.43; 95% CI 0.14-1.3). The percentage of cardiac arrests was 0.29% (4/1,367) versus 0.12% (3/2,410; OR 0.38; 95% CI 0.09-1.73) and the number of unexpected deaths was 0.36% (5/1,376) versus 0.17% (4/2,410; OR 0.42; 95% CI 0.11-1.59), (Table 3).

Secondary outcomes

The percentage of unplanned ICU admissions was 2.47% (34/1,376) in period 1 versus 4.15% (100/2,410) in period 2 (OR 1.66, 95% CI 1.07-2.55), Median APACHE II scores at unplanned ICU admission was 16 in period 1 versus 16 in period 2 (p = 0.68), and median ICU LOS was 3.5 days versus 3 days (p = 0.94). The number of deaths with a DNR order was 0.65% (9/1,376) versus 0.79% (19/2,410; OR 1.05; 95% CI 0.46-2.4).

Table 1 **Characteristics of study population before (period 1) and after (period 2) implementation of an RRS**

	Period 1 (n = 1,376)		Period 2 (n = 2,410)		p value
Age (SD)	55.4	(16.8)	58	(16.8)	<0.001*
Gender, male (%)	688	(50)	1295	(53.7)	0.027*
ASA (SD)	2.1	(0.8)	2.2	(0.8)	<0.001*
LOS hospital (IQR)	7	(5-13)	7	(5-13)	0.265
In-hospital deaths (per 1000 admissions)	18	(13.1)	37	(15.3)	0.573
Total ICU admissions (per 1000 admissions)	145	(10.5)	286	(11.9)	0.215
ICU admissions not due to an SAE (%)	111	(8.1)	186	(7.7)	0.701

SD Standard deviation
ASA American Society of Anesthesiologists classification
LOS Length of stay in days
IQR Inter quartile range
ICU Intensive care unit
SAE Serious adverse event
* Statistically significant at <0.05

Table 2 **Characteristics of patients with an SAE before (period 1) and after (period 2) implementation of an RRS**

	Period 1 (n = 34)		Period 2 (n = 91)		p value
Age (SD)	61.6	(17.6)	64.7	(12.5)	0.655
Gender, male (%)	21	(70)	65	(71)	0.851
ASA (SD)	2.3	(0.7)	2.5	(0.7)	0.107

SAE Serious adverse event
SD Standard deviation
ASA American Society of Anesthesiologists classification

Table 3 **Cardiac arrests and unexpected deaths before (period 1) and after (period 2) implementation of an RRS**

	Period 1 (n = 1,376)		Period 2 (n = 2,410)		OR*	95% CI for OR	p value
Patients with cardiac arrests and/ or unexpected deaths (%)	7	(0.5)	6	(0.25)	0.43	0.14-1.3	0.134
No. of cardiac arrests (%)	4	(0.29)	3	(0.12)	0.38	0.09-1.73	0.214
No. of unexpected deaths (%)	5	(0.36)	4	(0.17)	0.42	0.11-1.58	0.2

ICU Intensive care unit
IQR Interquartile range
LOS Length of stay in days
OR Odds ratio
* Logistic regressions adjusted for age, gender, and ASA
CI Confidence interval

Adherence to RRS procedures

A total of 37 SAEs were evaluable in period 1 and 101 SAEs in period 2. Observed abnormal EWS within 72 h before an SAE increased from 65% (24/37 events) to 91% (91/101 events; $p < 0.001$). Ward physician interventions increased from 38% (9/24 events) to 87% (79/91events; $p < 0.001$). In period 2, ward physicians consulted the MET in 64% (59/91 events), but in 16% (15/91 events) those consultations were seriously delayed for 1 or 2 days.

The overall MET dose was 56 per 1,000 admissions. The MET was called for 111 patients a total of 134 times. The main trigger that resulted in MET activation was increased respiratory rate and/or decreased oxygen saturation, which was found in 49% (60/122) of the recorded abnormal vital signs. The MET referred the patient to the ICU in 53% (59/134) of the MET reviews. In 20% (12/59 events), the ICU admission followed after MET interventions to stabilize the patient on the ward for 1 or 2 days. Of the patients subjected to one or more MET reviews, 9% (10/111 patients) died, of which 1.8% (2/111) unexpected, either in the ICU or in the ward after ICU discharge. Comparisons between the first and second year of the after study showed no statistical differences in any of the outcomes (data not shown).

Discussion

We studied the incidence of cardiac arrests and unexpected deaths in surgical patients before and after implementation of an RRS and the adherence of nurses and doctors to the RRS procedures. The number of patients who experienced a cardiac arrest and/or died unexpectedly declined with 50%. Unplanned ICU admissions increased significantly, but the APACHE II scores and the LOS of those admissions remained almost unchanged. We found a significant improvement in ward physician interventions to almost 90% of the events with an observed abnormal EWS. The MET was consulted in half of the events on the first day when an abnormal EWS was observed.

Although we showed a 50% reduction in the composite endpoint cardiac arrest and/or unexpected death, these results were not statistically significant probably due to the low baseline incidence. Reduction of cardiac arrests and unexpected deaths has been shown in studies with a higher baseline incidence compared with our study[19-23]. To show a statistically significant reduction of 50% in the composite endpoint cardiac arrests and/or unexpected death, we should have included almost 20,000 patients.

Surprisingly, we found a significant increase of unplanned ICU admissions. Many studies have shown no effect[23-25], whereas others found a decrease in unplanned ICU admissions[19,26]. However, in those studies no information on the adherence to the RRS was provided. The increase of unplanned ICU admissions could be explained because significantly more patients were detected as critically ill and were referred to the ICU. Disappointingly, after implementation of the RRS no significant decrease in the median APACHE II score at unplanned ICU admission or in the median unplanned ICU LOS was found, indicating that ICU referrals apparently were not done at an earlier stage of illness. Our MET dose was relatively high (56 per 1,000 admissions) compared with hospitals with a mature RRS (26-56 per 1,000 admissions)[19]. However, in our study, the MET was not consulted at all or consulted with a delay of 1 or 2 days in half of the events. Absent or delayed MET consults may be due to suboptimal adherence of the ward staff to the system. Furthermore, the two-tiered MET calling procedure may have delayed activation. Recent studies have shown that a delayed MET response was independently associated with greater risk of unplanned ICU admissions[14]and hospital mortality[12-14]. In addition, we found that in one out of five events, the MET chose to treat the patient on the ward for 1 or 2 days, whereas eventually the patient had to be transferred to the ICU. Therefore, it also is possible that the MET waited too long before transferring these patients to the ICU.

In the medical records of SAE patients, the number of records with reported abnormal

vital signs before an SAE increased significantly in the after study. A likely explanation is the introduction of the EWS and the training program for nurses. However, EWS recordings were frequently incomplete, which is of concern, because monitoring is essential for triage to an appropriate level of care[2]. Adopting an RRS is a complex process that needs time to become established as an integral part of the ward care system[15,27-29]. Even though we found a remarkable improvement in detecting and treating critically ill patients, our results show that further implementation strategies should be developed to improve adherence of the ward nurses and doctors to the RRS procedures and to stimulate the MET to refer the patient to the ICU at an earlier stage of deterioration.

Strengths and limitations of the study

The outcome "unexpected death" did not take into account patients who died in the operating room or patients who died after surgery on the ICU. We also excluded deaths with a DNR order from the primary outcome. Therefore, the outcome "unexpected death" is more informative to evaluate the effects of the RRS compared to the outcome measures "in hospital deaths" or "hospital mortality" used in other studies.

Our study had some limitations to take into consideration. First, in our study a single parameter track and trigger warning system was used. This system is comparable with the MET activation criteria studied by Cretikos et al., which have a positive predictive value of 10% and a sensitivity of 50%[30], implicating that the system often would trigger MET activation while the patient is not at risk for an adverse event, but also misses critically ill patients. This may have been of influence on the adherence of the ward staff to the system.

Second, in the medical records of SAE patients, often no exact time indication was recorded along with observed abnormal EWS. Therefore, timelines were defined in days on which ward physicians and MET were called following an abnormal EWS observation.

Third, we studied the effects of an RRS only in surgical patients, because it was expected that those patients would benefit most from the RRS system. However, a recent study showed that an RRS had a greater impact on cardiac arrest and mortality in medical patients compared with surgical patients[31]. Finally, this study was conducted in a single hospital; therefore, data may be less applicable to other study populations and settings. However, implementation of an RRS poses challenges in change of behavior, and only progressive accumulation of evidence and experience from different settings and situations will fill the gaps of knowledge to adjust the system to the specific needs of a certain setting[15].

Conclusions

Introduction of an RRS resulted in a nonsignificant decrease of 50% of patients who experienced a cardiac arrest and/or unexpectedly died. A low baseline incidence and delayed activation due to the two-tiered medical emergency team activation procedure and suboptimal adherence of the ward staff to the RRS procedures may have abated the positive results. Continued education en reinforcement is necessary for an RRS to be successful.

Acknowledgments

The authors thank students of the bachelor of nursing degree from the HAN for their contributions in gathering data. In particular, they thank Ans Rensen, lecturer on the bachelor of nursing degree.

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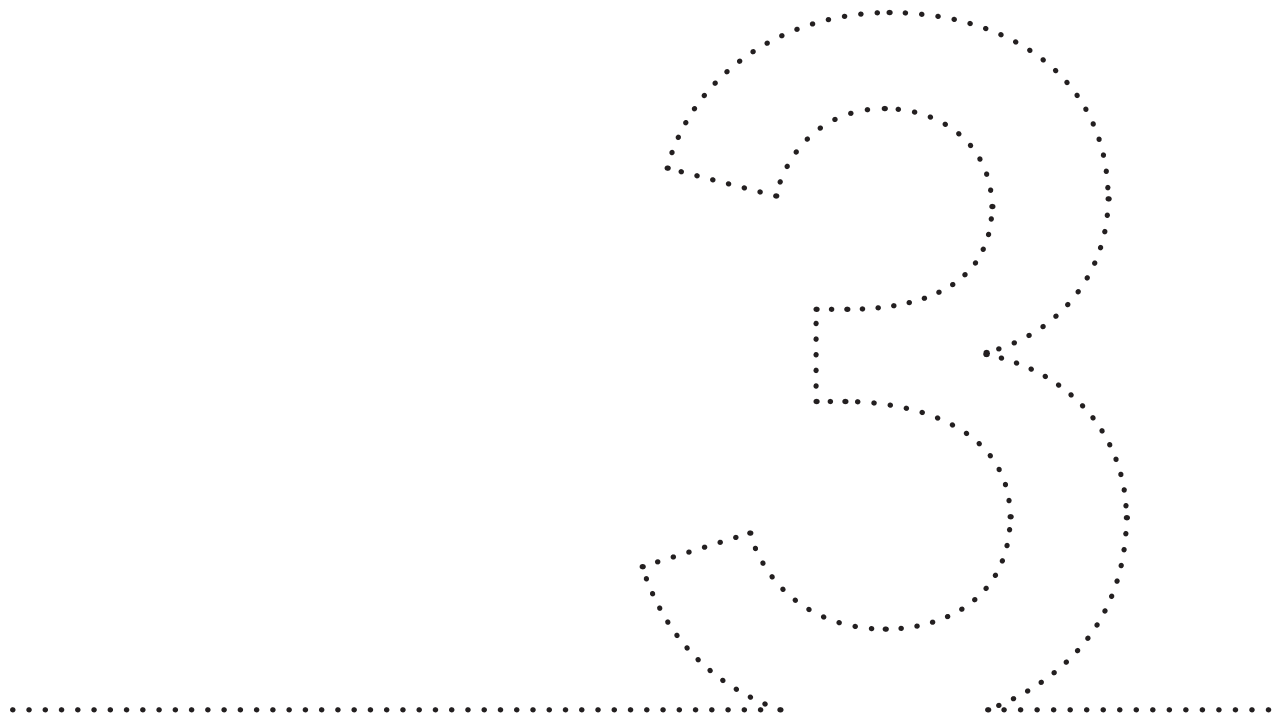
Effect of implementation of a rapid response system on protocol adherence in a surgical ward



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Journal of Hospital Administration 2014; 3 (3)

Abstract

Objective

To describe the implementation of a rapid response system and adherence to its afferent limb in order to identify key elements for improvement.

Implementation

We developed a multifaceted implementation strategy to introduce the rapid response system (RRS) on a 60-bed surgical ward of a university hospital. The strategy included the use of clear objectives, key leaders, an early warning score (EWS) observation protocol and a two-tiered medical emergency team (MET) warning protocol, a 1-day training program including a before-after knowledge test, mandatory for nurses and optional for ward physicians, reminders and feedback.

Study design and methods

We retrospectively analyzed a sample of 10,653 patient days and 101 medical records of patients with a serious adverse event (SAE). Outcome measures were early warning score (EWS) recording rates, the nurse to ward physician and the ward physician to the MET calling rates following abnormal EWS recordings, and the indicators triggering these calls.

Results

EWS recordings were present in 90% of the day shifts, 88% of the evening shifts and 80% of the night shifts. EWSs were recorded at least once in 92/101 medical records in the 3 days before an SAE; in 91/101 records EWSs were abnormal at least once. In case of an abnormal score, the nurse called the ward physician once or more in 87% (79/91). After being called by the nurse, the ward physician called the MET once or more in 75% (59/79). However, in 19% (15/79) there was a delay of one or two days before the ward physician/MET was called. Overall, medical emergency team calls were absent or delayed in over 50%.

Conclusions

After RRS implementation, recording of the EWS was high. Adequate warning in case of abnormal scores was suboptimal in nurses as well as ward physicians. Future implementation strategies should therefore be aimed at the interdisciplinary team.

Introduction

Most patients experience physiologic instability up to 48 hours prior to a serious adverse event (SAE)[1-4]. These warning signs are often not recognized or inadequately treated by the ward staff. Early recognition and treatment of abnormal vital signs is essential to prevent SAEs, such as cardiac arrest, death and unplanned intensive care unit (ICU) admissions. Based on these considerations the concept of the rapid response system (RRS) was developed. An RRS consists of an afferent limb (detecting patients at risk and obtaining adequate help), an efferent limb (consisting of a dedicated rapid response team) and an administrative and data analysis limb[5]. The RRS is highly recommended by the Institute for Healthcare Improvement[6] and implemented in many countries[7].

Background

Implementing an RRS is a complex process[8-12]. Even in matured RRSs, failure of the afferent limb is a persistent problem[13] which may result in cardiac arrests[14], hospital mortality[10,15,16] or increased unplanned ICU admissions[10,17]. Until now, studies on the effects of an RRS remain equivocal[7,18-20]. Failure of implementation may partly explain these results[8].

We implemented an RRS on the surgical ward and showed a statistically non-significant reduction in the number of cardiac arrests and/or unexpected deaths from 0.5% (7/1,376) before, to 0.25% (6/2,410) after implementation (odds ratio 0.43; 95% confidence interval 0.14-1.3)[21]. In contrast, the number of unplanned ICU admissions increased from 2.47% (34/1,376) before, to 4.15% (100/2,400) after implementation (odds ratio 1.66; 95% confidence interval 1.07-2.55). We concluded that the decrease in cardiac arrests and/or unexpected deaths was not statistically significant partly due to the low baseline incidence. In addition, suboptimal adherence of the ward staff to the RRS procedures may also have been of influence.

The aim of this study was to describe the strategy used to implement the RRS and to measure the adherence of the ward staff to its afferent procedure in order to identify key elements for further improvement.

Implementation

The RRS was implemented in a 60-bed surgical ward of a 960-bed university hospital in the Netherlands. Patients were admitted to the surgical ward for general surgery, including central or extensive peripheral vascular surgery, major oncologic surgery, lung surgery, extensive abdominal surgery, and trauma.

A multifaceted RRS implementation strategy was developed in 2006 and introduced between January and April 2007. The strategy included: setting clear objectives, appointing key leaders, introducing a tailored RRS procedure and a 1- day training program for nurses and ward physicians, and the use of follow-up reminders and feedback.

The objective of the RRS was to detect surgical patients at risk and treat them on the ward or assign them to a higher level of care in a timely manner. The implementation was supported by a group of key nurses and key physicians from the surgical ward and the ICU and led by the project chair. The project chair was a research nurse from the intensive care. The key leaders developed an RRS adjusted to the hospital needs, based on the international consensus document on medical emergency teams (MET)[5]. They informed the nursing and medical staff about the theory and purpose of the RRS during staff meetings, supported by written information.

The protocol for early detection of patients at risk includes observation of the early warning score (EWS) and documentation of the EWS in the daily patient records by the nurses, three times a day. A single-parameter EWS was chosen, including the following criteria for abnormal vital signs: respiratory rate <8 or >30 per minute, O_2 saturation <90%, systolic blood pressure <90 or >200 mm Hg, heart rate <40 or >130 per minute, a decrease of two points in the eye, motor, verbal (EMV) score, or if the nurse felt worried[22].

The protocol for obtaining adequate help was two-tiered. In the first tier, nurses had to call the ward physician immediately if one of the EWS warning criteria was met. Ward physicians were junior doctors, present in the hospital 24/7. The ward physician had to evaluate the patient at the bedside within 10 minutes. In the second tier the ward physicians activated the MET immediately if a serious situation existed or if the patient did not stabilize after an initial intervention. The ward physician was included to maintain continuity of care and limit the workload of the MET, in accordance with regular practice in the Netherlands[23]. The MET consisted of a critical care physician and a critical care nurse from the ICU. The MET was available 24/7. Finally, the SBAR (situation; background; assessment; and recommendation), a standardized way of communicating in critical situations[24] was introduced in the protocol for both nurses and ward physicians.

A 1-day training program for nurses and ward physicians was developed, consisting of a theoretical part, a practical part focusing on the afferent procedure, and a discussion about ethical dilemmas related to the system. The practical part was a simulation-based training, focusing on detection of the critically ill patient and communicating according to SBAR. The program was mandatory for nurses and optional for ward physicians. Approximately 90% of the nurses and 5% of the ward physicians attended the training.

Nurses completed a knowledge test before- and after the training program. This knowledge test mainly included criteria for abnormal EWSs, and nurses could score a maximum of 100 points. Nurses completed the test during a team meeting within a period of three weeks before, and two to four weeks after the training program. In addition, nurses were asked to describe their perception of the RRS after having followed the training program. Nurses completed the EWS knowledge test before the training program in 64% (60/94) and after the training program in 56% (52/94). The score increased significantly from a median of 20 (IQR 10-30) to a median of 90 points (IQR 70-100, Mann-Whitney U 33, $p<0.001$). Nurses' perception on the RRS was positive. In particular, nurses were convinced that the availability of a MET would positively influence the quality of care for critically ill patients.

Reminders shaped in pocket-sized, laminated cards with the EWS criteria, the SBAR communication scheme, and the MET beeper number was given to the ward staff. Posters with the EWS criteria and the MET beeper numbers also were displayed in the wards. In addition, extra pulse oxymetry monitors were available on the ward and the EWS criteria were printed on the daily patient charts.

Feedback was given by newsletters showing EWS recording rates on the daily patient charts, nurse to ward physician and ward physician to MET calling rates, and the time-interval between calls and arrival of the ward physician/MET. Newsletters were published every two months for nurses and every six months for ward physicians. Furthermore, progress of the RRS was discussed during regular staff meetings and at a special meeting once a year.

Study design and methods

We performed a retrospective analysis of daily patient charts. Furthermore, we analyzed medical records of patients who experienced an SAE. The need for informed consent was waived by the Medical Ethics Committee of district Arnhem-Nijmegen (MEC number: 2005/310).

To measure the effectiveness of our implementation strategy on afferent protocol adherence, we used the following outcome measures: EWS recording rates on the daily patient charts, EWS recording rates in the medical records of patients with an SAE, the nurse to ward physician and the ward physician to MET calling rates following abnormal EWS recordings and the indicators triggering these calls.

A EWS was defined as complete if all EWS criteria were recorded. An SAE was defined as an unplanned ICU admission from the ward, a cardiac arrest or an unexpected death. The nurse to ward physician calling rate was defined as the number of ward physician calls from

the nurse, divided by the number of days one or more abnormal EWSs were recorded. The ward physician to MET calling rate was defined as the number of MET calls from the ward physician divided by the number of days on which the ward physician was called by the nurse for an abnormal EWS.

We analyzed a sample of 10,653 patient days from 1,601 patients admitted at the ward during the period January 2008 to July 2009. Furthermore, we analyzed 101 medical records of patients who experienced an SAE between April 2007 and April 2009. Data were retrieved from the medical records starting 2 days before the day an SAE occurred, classified as day -2, day -1, and day 0. We retrieved information about the nurse to the ward physician calls from the medical records and information about the ward physician to the MET calls from the electronic MET registration database.

Results

EWS recording rates in the daily patient charts

Figure 1 shows the percentage of vital signs recorded during the daytime, evening and night. Complete EWS recordings were present in 90% of the day shifts, 88% of the evening shifts and 80% of the night shifts.

EWS recording rates in the medical records of SAE patients and the calling rates following abnormal EWS recordings

Table 1 shows the EWSs recording rates in the medical records before an SAE, stratified per day. EWS recordings increased from 58% (58/101) on day -2, to 86% (87/101) on day 0. Often no exact time indication was retrievable from the record.

Of the recorded EWSs, the percentage abnormal EWSs increased from 31% (18/58) on day -2 to 92% (80/87) on day 0. In case of observed abnormal EWSs, nurses called the ward physician in 61% (11/18) on day -2 to 88% (70/80) on day 0. After being called by nurses, ward physicians called the MET in 27% (3/11) on day -2 to 74% (52/70) on day 0.

Figure 2 shows the EWS recordings in the medical records stratified per SAE. Recorded EWSs were abnormal at least once in 91% (91/101) in the three days before the event. In 87% (79/91) the nurse called the ward physician once or more. After being called by the nurse, the ward physician called the MET once or more in 75% (59/79). In 19% (15/79) the ward physician tried to stabilize the patient on the ward during one or two days before calling the MET. Overall, in 48% (44/91) of the SAEs with recorded abnormal EWSs, the

MET was called on the same day the abnormal EWS was observed. Comparisons between the first and second year after RRS implementation showed no statistical differences in any of the outcomes (data not shown).

Indicators triggering calls

Table 2 shows the nurse to ward physician and ward physician to MET triggering rate per vital sign. Abnormal EWSs were recorded in 46% (138/303) of the days before an SAE. In 72% (100/138) information was given on the vital signs triggering the call for help and a total of 122 abnormal vital signs were registered. In 7% (9/138) the nurse called the ward physician due to the worried criterion. In the remaining 21% (29/138) no information was available on which EWS criterion triggered the call.

Nurses called the ward physician less often in cases of decreased systolic blood pressure (62%) and decreased oxygen saturation (75%). Ward physician called the MET less often in cases of decreased systolic blood pressure (56%), and increased heart rate (55%). Recorded vital signs tended to be worse on day 0 compared with day -2 and day -1, although the differences were not significant (data not shown).

Table 1 **EWS recordings in the medical records and calling rates before an SAE stratified per day**

	Day 2		Day 1		Day 0	
	n	%	n	%	n	%
EWS recorded in medical records (% of SAEs)	58	(58)	75	(75)	87	(86)
Abnormal EWS (% of recorded EWSs)	18/58	(18)	40/75	(53)	80/87	(92)
Ward physician calls from the nurses (% of abnormal EWSs)	11/18	(61)	32/40	(80)	70/80	(88)
MET calls from the ward physician (% of ward physician calls in abnormal EWSs)	3/11	(27)	11/32	(34)	52/70	(74)

n 101 SAEs
EWS Early warning score
SAE Serious adverse event
Day 2 Two days preceding the SAE
Day 1 One day preceding the SAE
Day 0 The day of the SAE
MET Medical emergency team

Table 2 **Indicators triggering ward physician and MET calls**

Indicator	Abnormal scores	Ward physician calls	(%)	MET calls	(%)	% of abnormal scores
Increased respiratory rate	32	29	90	22/29	76	69
Decreased oxygen saturation	28	21	75	18/21	86	64
Decreased systolic blood pressure	40	25	62	14/25	56	35
Decreased conscious state	10	9	90	6/9	67	60
Increased heart frequency	12	11	92	6/11	55	50

n 100 abnormal EWS
MET Medical emergency team

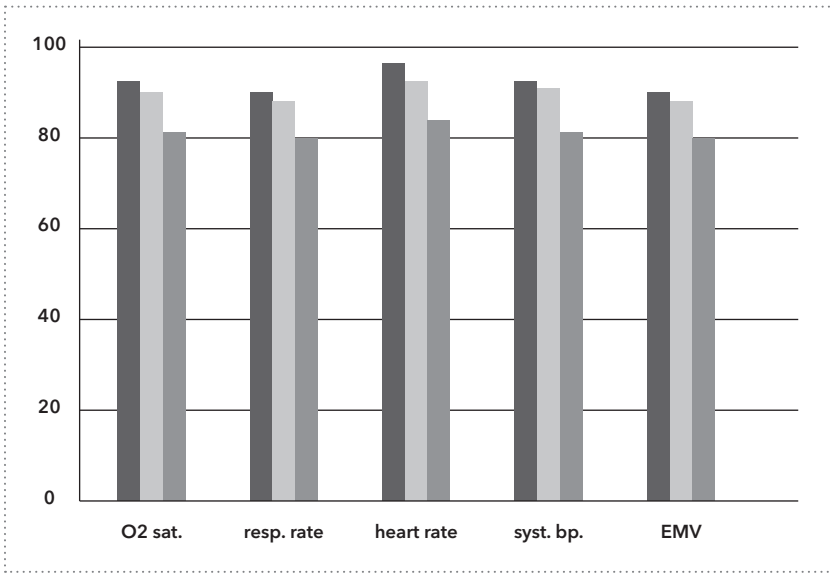

Figure 1 **Percentage of vital signs recorded in the daily patient charts**

n 10,653 patient days
Day
Evening
Night
EMV Eye, motor, verbal score

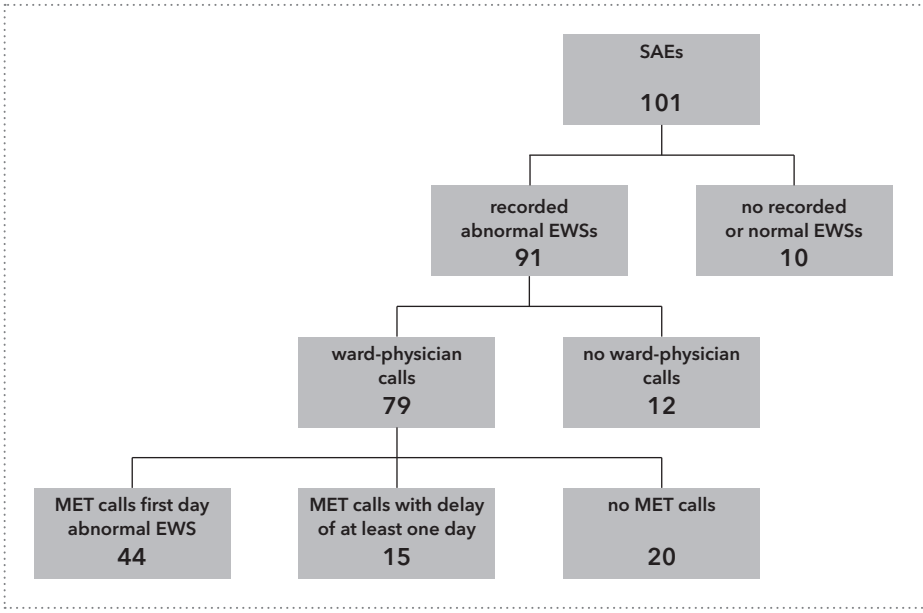

Figure 2 **EWS recordings in the medical records and calling rates ≤72 hours before an SAE, stratified per SAE**

SAE Serious adverse events
EWS Early warning score

Discussion

We described the implementation of an RRS on a surgical ward and the adherence to its afferent procedure in order to find key elements for improvement. Although the EWSs were observed in a large number of patient days, registration of those vital signs in medical records was often incomplete or missing. In 91% of the medical records of SAE patients the EWS was abnormal at least once in the 2 days before the day an SAE occurred. The MET was called on the same day in only half of the SAE patients.

Our findings of delayed or absent MET calls in over 50% are of concern, since studies showed an association between MET consult delays and SAEs[10,14-17,25]. Regular monitoring of vital signs is the first and foremost step of the afferent procedure for detecting critically ill patients. Our data show that nurses' knowledge of the EWS was adequate. Also complete EWS recordings in 80%-90% of the patient charts, depending on time of day, was acceptable. These results can probably be attributed to the multifaceted implementation

strategy that we adopted. In the literature, initial simulation training[26-28], knowledge of the warning criteria and reinforcement regarding the warning protocol have been identified as effective ways of introducing or improving the use of an RRS[26,29]. However, there was a lower observation frequency at night time compared with daytime. This fact has been shown by others[30]. To minimize sleep disturbances, nurses may be reluctant to observe EWSs during the night. Even though there is no international consensus concerning the frequency at which EWS observations should be made, a time interval of 12 hours may be too long[31]. Furthermore, less EWS values were copied from the daily patient charts in the medical records and often without an exact time indication. A patient's vital signs history should be easily accessible for clinicians[31]. This information is of importance in order to interpret actual vital scores.

Both nurses and ward physicians were less likely to call for help on days -2 and -1 compared with the day of the SAE itself. This may be partly explained by the fact that some patients were temporarily stabilized after a ward staff intervention. Possible other explanations for our findings are that ward staff underestimated the patient's risk of further deterioration. Most ward physicians are juniors and often lack the knowledge and experience to recognize medical emergency situations[32]. As only 5% of the ward physicians attended the one-day training program, this may certainly play a role. In contrast, ward staff may have felt that they were able to handle the situation by themselves[33,34]. For example, Pantazopolous (2012) found that nurses with a higher level of education or who attended a resuscitation course were less likely to call for help[35]. Furthermore, ward staff may have felt uncertain to call for help even when the patient met the warning criteria[34]. Nurses often rely on other nursing team members instead of procedures when making their decisions[36,37]. Nurses' and ward physicians' uncertainty increases when the attending ward physicians or MET do not expect them to follow procedures too rigorously[27,33,38,39], or when they get mixed messages from their leaders when asking for help[40,41].

To improve timely MET consultations, the next step could be to allow nurses to call the MET directly. However, this would undoubtedly result in an increased workload for the MET. For example, a study using almost the same warning criteria, found that 18% of all general ward patients showed abnormal scores at least once during admission[42]. This would result in MET calls in almost one out of five admitted patients. Moreover, research has shown that ward physicians prefer to be called first and nurses prefer to call the responsible ward physician, before calling the MET[9,33,41,43,44], thereby involving ward physicians in the treatment of the patient at risk.

The low calling rate in case of a decreased systolic blood pressure of < 90 mm is remarkable.

Even though changes in systolic blood pressure alone do not predict adverse events[45,46], a decreased systolic blood pressure together with a decrease in urinary output, and/or respiratory changes and/or a decrease in consciousness is associated with a higher risk of death, as is a decreased systolic blood pressure with an abnormal blood gas analysis[46,47]. The low calling rate was also seen in case of decreased oxygen saturation and an increased heart rate. A decreased oxygen saturation of 90% or lower and an increased heart rate of >120 per minute are both associated with 5%-10% mortality, whereas a heart rate of >150 per minute is associated with 20% mortality[46]. A timely response on these abnormal vital signs is therefore of importance.

Key elements for improvement

First, in order to increase accessibility for clinicians to patients' vital signs history, documentation of the observed vital signs into the medical records is needed.

Second, delays in calling for help when abnormal EWSs are observed should be minimized. Ward physicians play a crucial role and should encourage ward nurses to call them immediately when vital signs are abnormal, and they themselves should be encouraged to call the MET immediately if the patient's condition is critical or if the patient does not stabilize after initial treatment. To accomplish this, interdisciplinary team training on how to interact and manage unexpected critically ill patients may be helpful to improve collaboration. However this training alone will probably not suffice since Fuhrmann (2009) showed that a one-day simulation based multi-professional training of staff did not affect staff awareness of patients at risk on the wards[42]. Consensus of shared perceptions regarding patient safety norms and behaviors by the ward staff is a premise for patient safety and successful quality improvement interventions[48]. This implicates that training programs concerning critically ill patients should be team oriented and integrated in a broader safety intervention program[49]. In addition, support by management facilitates activation of rapid response teams[43]. Thus, leadership is also an important component of implementation strategies for improving patient safety norms and behaviors.

Third, since the ward staff was less likely to call for help in case of a decreased systolic blood pressure, decreased oxygen saturation and an increased heart rate, the introduction of the aggregated, weighted parameter 'track and trigger' system (AWTTS)[50] may be considered as an aid to better interpret the deviations of one or more vital signs. The AWTTS allocates points to the vital parameters in a weighted manner. Since higher scores are associated with worse outcomes[51], the use of an aggregated system may convince ward nurses and ward physicians to call for help if the score increases.

Limitations of the study

First, since this study took place in one surgical ward of a Dutch university hospital, the relevance for other settings is unclear, although afferent limb failure is a frequently reported problem. Second, although we included many patient days at risk, our sample included only 101 SAEs. Third, due to the retrospective character, we probably missed some observed, but not recorded abnormal EWS occurrences. In addition, since exact time indications were often missing along with recorded abnormal EWSs, timelines were defined in days on which ward physicians and MET were called following an abnormal EWS observation.

Conclusions

Use of a tailored multifaceted strategy for implementation of the RRS, resulted in sufficient monitoring of vital signs by ward nurses. However, the afferent limb showed deficiencies in documentation of vital signs in the medical records and calls for help by the ward nurse and the ward-physician in case of observed abnormal EWSs. Our initial implementation strategy was primarily aimed at the ward nurses, future implementation strategies should be aimed at the interdisciplinary ward team.

Acknowledgements

The authors would thank students and Ans Rensen, lecturer of the bachelor of nursing degree from the HAN University for their contributions in gathering data. They also would thank Monique Born who tested the nurses' EWS knowledge.

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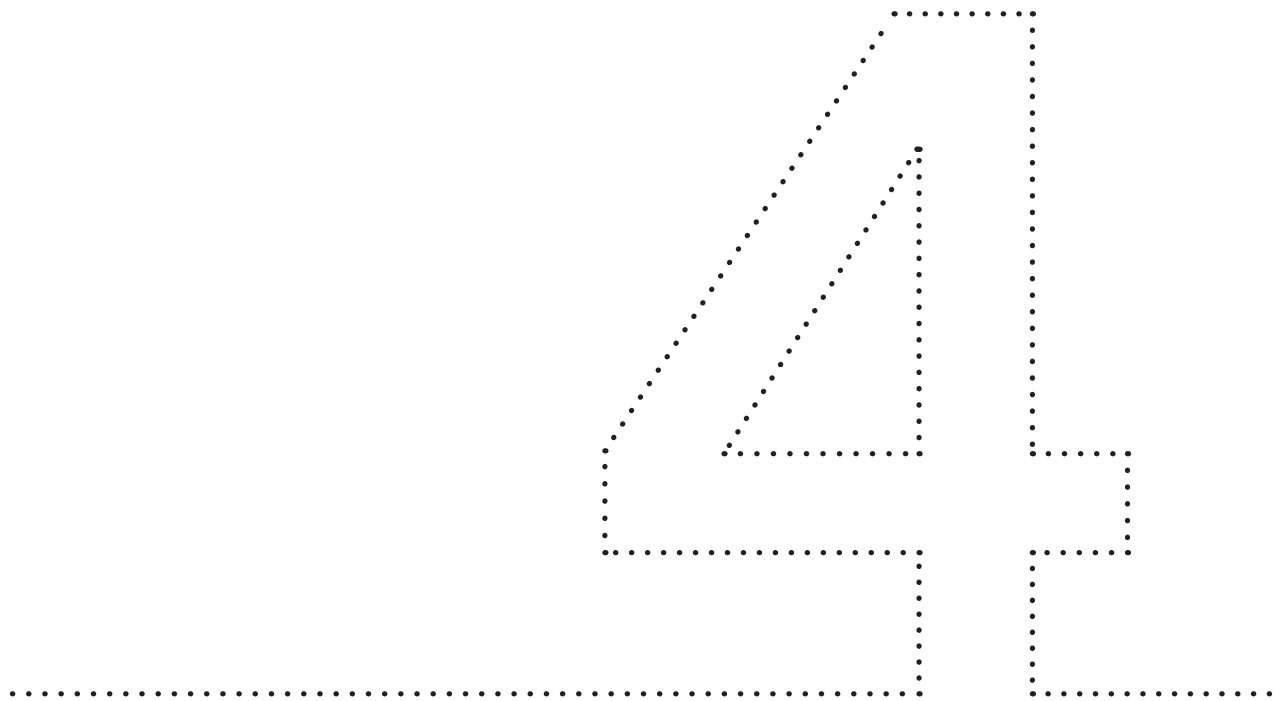
Effects of a rapid response system on quality of life: a prospective cohort study in surgical patients before and after implementing a rapid response system



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Health and Quality of Life Outcomes 2013; 74 (11): 7525-11-74

Abstract

Background

The aim of a rapid response system (RRS) is to improve the timely recognition and treatment of ward patients with deteriorating vital signs. The system is based on a set of clinical criteria that are used to assess patient's vital signs on a general ward. Once a patient is evaluated as critical, a medical emergency team is activated to more thoroughly assess the patient's physical condition and to initiate treatment. The medical emergency team included a critical care physician and a critical care nurse.

Aim

To assess the effect of an RRS on health-related quality of life (HRQOL).

Methods

Prospective cohort study in surgical patients before and after implementing an RRS. HRQOL was measured using the EuroQol-5 dimensions (EQ-5D) and the EQ visual analogue scale (VAS) at pre surgery and at 3 and 6 months following surgery.

Results

No statistical significant effects of RRS implementation on the EQ-5D index and EQ-VAS were found. This was also true for the subpopulation of patients with an unplanned intensive care unit admission. Regarding the EQ-5D dimensions, deterioration in the 'mobility' and 'usual activities' dimensions in the post-implementation group was significantly less compared to the pre-implementation group with a respective mean difference of 0.08 ($p=0.03$) and 0.09 ($p=0.04$) on a three-point scale at 6 months. Lower pre-surgery EQ-5D index scores and higher American Society of Anesthesiologists physical status (ASA-PS) scores were significantly associated with lower EQ-5D index scores at 3 and 6 months following surgery.

Conclusions

Implementation of an RRS did not convincingly affect HRQOL following major surgery. We question if HRQOL is an adequate measure to assess the influence of an RRS. Pre-surgery HRQOL- and ASA-PS scores were strongly associated with HRQOL outcomes and may have abated the influence of the RRS implementation.

Introduction

Rapid response systems (RRSs) are considered a powerful tool in patient safety. The aim of an RRS is to improve the timely recognition and treatment of general ward patients with deteriorating vital signs. The system is based on a set of clinical criteria that are used to assess patient's vital signs on a general ward. Once a patient's status is evaluated as critical according to these criteria[1], a rapid response team is activated to more thoroughly assess the patient's physical condition and to initiate treatment[2].

The most frequently used outcome measure to evaluate the effectiveness of an RRS is the incidence of serious adverse events (SAEs), including cardiac arrest rate, (unexpected) death and unplanned intensive care unit (ICU) admission[3-6]. Previously, we showed that the introduction of an RRS on a surgical ward resulted in a statistically non- significant decrease in patients who experienced a cardiac arrest and/or who died unexpectedly on the ward while unplanned ICU admissions of patients increased significantly[7]. In addition to these medical outcomes, quality of life measures are also becoming increasingly important to health care research. Quality of life outcomes reflect a patient's health perspective and are relevant to better understand and improve healthcare expenditure and resource utilisation in patient care[8]. We hypothesized that the RRS system would positively influence patient's quality of life. The aim of the current study was to estimate the effect of an RRS on the quality of life at 3 and 6 months following surgery in the entire study population and in the subset of patients with an unplanned ICU admission.

Methods

We measured health-related quality of life (HRQOL) at pre-surgery and at 3 and 6 months following surgery in patients admitted to the surgical ward of a university hospital. Measurements were taken over two 12-months periods. Period 1 was conducted before the implementation of an RRS from January 2006 until December 2006. Period 2 was conducted after implementation of an RSS from April 2007 until April 2008. The local medical ethics committee waived the need for informed consent.

In our study we included patients staying on the surgical ward ≥72 hours because of major general surgery, including central or extensive peripheral vascular surgery, major oncologic surgery, lung surgery, extensive abdominal surgery and trauma. The 72-hours limit was used to exclude patients with minor surgical procedures. Patients unable to communicate

effectively were also excluded. In period 1, a convenience sample of 518 of 1376 eligible patients were screened for participation and in period 2, 549 of 2410 patients.

HRQOL was measured using the Euroqol 5 dimensions (EQ-5D) and Euroqol visual analogue scale (EQ-VAS) questionnaire, an extensively validated instrument and approved by the Euroqol Translation Committee[9]. EQ-5D measures the following health dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each dimension is divided into three levels: level 1= no problems, level 2= some/moderate problems, level 3=severe/ extreme problems. The EQ-5D index values are derived from a general Dutch population sample[10] and range from minus 0.33 to plus 1. The EQ-VAS measures overall health on a scale from 0 to 100.

In addition, socio-demographic and clinical variables influencing HRQOL were recorded. These included age, sex, education level, employment status and smoking behaviour[11,12]. We also recorded the length of stay (LOS) of planned and unplanned ICU admissions and the American Society of Anaesthesiologists physical status (ASA-PS) classifications score at ICU admission.

The RRS system was introduced in January 2007 and was fully operational by April 2007. The system required ward nurses to systematically observe and record patient's vital signs at least three times daily. If nurses felt worried about a patient's condition or observed abnormal vital indicators, then they were instructed to immediately call the ward physician. Abnormal vital indicators included respiratory rate <8 or >30 per minute, oxygen saturation <90%, systolic blood pressure <90 or >200 mm Hg, heart rate <40 or >130 per minute, and a decrease of two points in the eye, motor, and verbal (EMV) score[13]. Once called, the ward physician was required to evaluate the patient at bedside within 10 minutes and to immediately call the medical emergency team (MET) if the patient's condition was serious or if the patient did not stabilise after an initial intervention. The MET included a critical care physician and a critical care nurse. If the ward physician could not see the patient within 10 minutes, nurses were instructed to activate the MET directly.

Data collection

Eligible patients were approached on the surgical ward before surgery, or in the case of emergency surgery, immediately after surgery. The research assistant explained the study objectives orally and in writing. Participating patients were asked to fill in the EQ-5D and EQ-VAS based on their condition the day before hospital admission. Patients were also asked to fill in the questionnaires at 3 and 6 months after surgery. Non-responders were contacted twice. Additional clinical variables were retrieved from the hospital's electronic databases.

Statistical analysis

Normally distributed data were parametrically tested with the independent Student's t test, non-normally distributed data with the Mann–Whitney U test, and nominal data with the chi-square test. Differences in HRQOL outcomes in period 1 and 2 were tested with the analysis of covariance (ANCOVA). At Pre- surgery the fixed factors 'gender', 'ASA-PS' and the covariate 'age at admission' were used. At the 3- and 6-month follow-up, the covariates 'EQ-5D pre-surgery' or 'EQ-VAS pre-surgery' and 'planned ICU LOS' were also used. In addition, we compared HRQOL in period 1 and 2 in a subset of patients with unplanned ICU admissions. For statistical analysis, the statistical package for the social sciences (SPSS) version 17 was used. In our analysis a $p<0.05$ was considered statistically significant.

Results

In period 1, 84% (437/518) of the screened patients were included in the study, while in period 2, 85% (466/549) of the screened patients were included (Figure 1). Table 1 shows the characteristics of the in- and excluded patients. Excluded patients were not significantly different from included patients regarding gender or age. However, the ASA-PS score of excluded patients was 0.3 points ($p<0.001$) higher in both periods. Demographics for the final study group are shown in Table 2. Patients lost to follow up were significantly younger: 6 years *($p=0.05$)* in period 1, and 8 years (*$p\leq0.01$*) in period 2.

Effects of RRS implementation on quality of life

Figure 2 shows the results of RRS implementation on the quality of life. In both period 1 and 2 patients' HRQOL was improved at 3 and 6 months following surgery. When we compared period 1 and 2, there were no statistical differences in either the EQ-5D index (0.72 versus 0.73, *$p=0.54$* at 3 months following surgery and 0.70 versus 0.72, *$p=0.29$* at 6 months following surgery) or the EQ-VAS scores (67 versus 65, *$p=0.28$* at 3 months following surgery and 67 versus 67, *$p=0.80$* at 6 months following surgery).

This was also true for patients with an unplanned ICU admission. HRQOL, however, decreased at 3 months and was near pre-surgery level at 6 months following surgery. In this subset of patients the EQ-5D index was 0.61 versus 0.61, *$p=0.99$* at 3 months following surgery and 0.62 versus 0.66, *$p=0.79$* at 6 months following surgery while the EQ-VAS was 69 versus 70, *$p=0.91$* at 3 months following surgery and 71 versus 65, *$p=0.56$* at 6 months following surgery.

EQ-5D dimensions

Results of the EQ-5D dimensions are shown in Table 3. In both period 1 and 2, patients reported fewer problems on the EQ dimensions 'pain/discomfort' and 'anxiety/depression' but more problems with 'mobility', 'self-care' and 'usual activities' at 3 and 6 months following surgery. In period 2 at 6 months, however, patients experienced slightly less deterioration regarding 'mobility' and 'usual activities' than they did in period 1 (mean difference between period 1 and 2 was 0.08, $p=0.03$ for 'mobility' and 0.09, $p=0.04$ for 'usual activities' on a 3 point scale).

Variables related with HRQOL outcomes

Table 4 shows the results for variables related to HRQOL outcomes. The pre-surgery EQ-5D index and ASA scores were significantly related to the EQ-5D index at 3 and 6 months following surgery ($p\leq0.01$ for EQ-5D and ASA at 3 months, $p\leq0.01$ for EQ-5D and $p=0.02$ for ASA at 6 months). Gender, age and LOS of planned ICU admissions were not significantly related with EQ-5D index scores at 3 and 6 months following surgery.

Table 1 **Characteristics of excluded and included patients**

	Excluded	Included	p-value
Before RRS implementation	n=81	n=437	
Gender male (%)	40 (49)	225 (52)	0.58
Mean age mean (SD)	57 (21)	56 (15)	0.41
ASA-PS (SD)	2.3 (0.9)	2.0 (0.8)	0.01
After RRS implementation	n=83	n=466	
Gender male (%)	42 (51)	239 (51)	0.83
Age mean (SD)	61 (18)	58 (16)	0.07
ASA-PS (SD)	2.4 (0.8)	2.1 (0.7)	<0.01

RRS Rapid response system
SD Standard deviation
ASA-PS American Society of Anesthesiologists physical status

Table 2 **Characteristics of included patients**

	Before n=437		After n=466		p-value
Gender male (%)	225	(51.5)	239	(51.3)	0.95
Mean age mean SD)	56.1	(15.3)	57.8	(16.2)	0.37
ASA PS mean (SD)	2.03	(0.8)	2.08	(0.7)	0.16
Unemployed (%)	6	(1.4)	8	(1.7)	0.54
Education, low level (%)	46	(10.9)	62	(13.3)	0.28
Smoking (%)	70	(16.3)	77	(16.6)	0.92

Before *Before implementing the rapid response system (RRS)*
After *After implementing the RRS*
ASA-PS American Society of Anesthesiologists physical status
SD Standard deviation

Table 3 **EQ-5D dimensions of surgical patients**

	before		after		differences of mean	CI	p-value
	n	mean	n	mean			
Mobility							
Pre-surgery	437	1.57	466	1.53	0.04	-0.43-0.12	0.36
3 months after surgery	396	1.76	437	1.73	0.04	-0.04-0.10	0.28
6 months after surgery	377	1.79	397	1.72	0.08	0.01-0.14	0.03*
Self-care							
Pre-surgery	437	1.26	466	1.25	0.02	-0.05-0.08	0.63
3 months after surgery	396	1.54	437	1.57	-0.03	-0.09-0.04	0.42
6 months after surgery	377	1.45	397	1.48	-0.03	-0.09-0.03	0.3
Usual activities							
Pre-surgery	437	1.72	466	1.75	-0.03	-0.12-0.07	0.56
3 months after surgery	396	1.98	437	1.92	0.05	-0.04-0.14	0.24
6 months after surgery	377	1.93	397	1.84	0.09	0.00-0.18	0.04*
Pain/discomfort							
Pre-surgery	437	1.91	466	1.86	0.05	-0.05-0.15	0.33
3 months after surgery	396	1.76	437	1.77	-0.01	-0.09-0.06	0.74
6 months after surgery	377	1.72	397	1.73	-0.01	-0.09-0.07	0.82
Anxiety/depression							
Pre-surgery	437	1.53	466	1.52	0.00	-0.08-0.09	0.96
3 months after surgery	396	1.45	437	1.42	0.02	-0.05-0.09	0.49
6 months after surgery	377	1.43	397	1.42	0.02	-0.05-0.09	0.62

before Before implementing the rapid response system (RRS)
after After implementing the RRS
EQ-5D Euroqol 5 dimensions, scale 1–3 (1 = no problems, 2 = some/moderate problems, 3 = severe/ extreme problems)
ASA-PS American Society of Anesthesiologists physical status
Pre-surgery: fixed factors: gender, ASA-PS
covariates: age at admission
Following surgery: fixed factors: gender, ASA-PS; covariates: age at admission, length of stay planned intensive care admission, EQ-5D dimension pre surgery
* p≤0.05 statistical significant

Table 4 **Variables related with health-related quality of life outcomes**

	ASA	B	95% CI
3 months after surgery			
Intercept		0.12	-18 – 0.43
Before RRS implementation vs after		- 0.02	- 0.05 – 0.02
Gender, male vs female		0.02	- 0.02 – 0.05
Age		≤ 0.01	≤ - 0.01 – ≤ 0.01
LOS planned ICU		≤ 0.01	≤ - 0.01 – ≤ 0.01
ASA 1 to 4 vs ASA 5	1	0.42	0.14 – 0.71
	2	0.41	0.12 – 0.69
	3	0.34	0.05 – 0.62
	4	0.37	0.06 – 0.68
EQ-5D pre surgery		0.26	0.21– 0.31
6 months after surgery			
Intercept		0.25	- 0.04 – 0.54
before RRS implementation vs after		- 0.01	- 0.05 – 0.02
Gender, male vs female		0.03	≤ -0.01 – 0.06
Age		≤ 0.01	≤ -0.01 – ≤ 0.01
LOS planned ICU		≤ 0.01	≤ -0.01 – ≤ 0.01
ASA 1 to 4 vs ASA 5	1	0.32	0.05 – 0.60
	2	0.28	0.01 – 0.56
	3	0.25	- 0.02 – 0.52
	4	0.26	- 0.05 – 0.56
EQ-5D pre-surgery		0.24	0.19 – 0.29

EQ-5D *Euroqol 5 index scale -0.33–1*
RRS *Rapid response system*
ASA *American Society of Anesthesiologists physical status*
LOS planned ICU *Length of stay planned intensive care unit admission*
CI *Confidence interval*

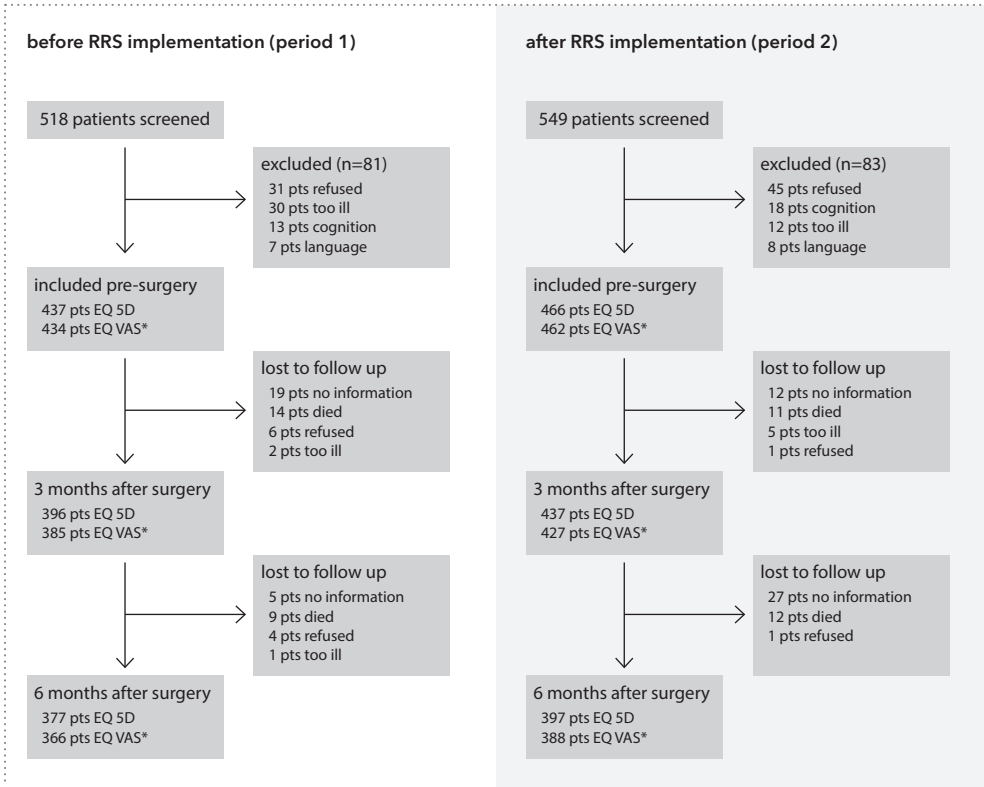

Figure 1 **Overview of included surgical patients**

RRS Rapid response system
EQ-5D Euroqol 5 dimensions
Q VAS Euroqol visual analogical scale
pts Patients
* Not all patients filled in the VAS score

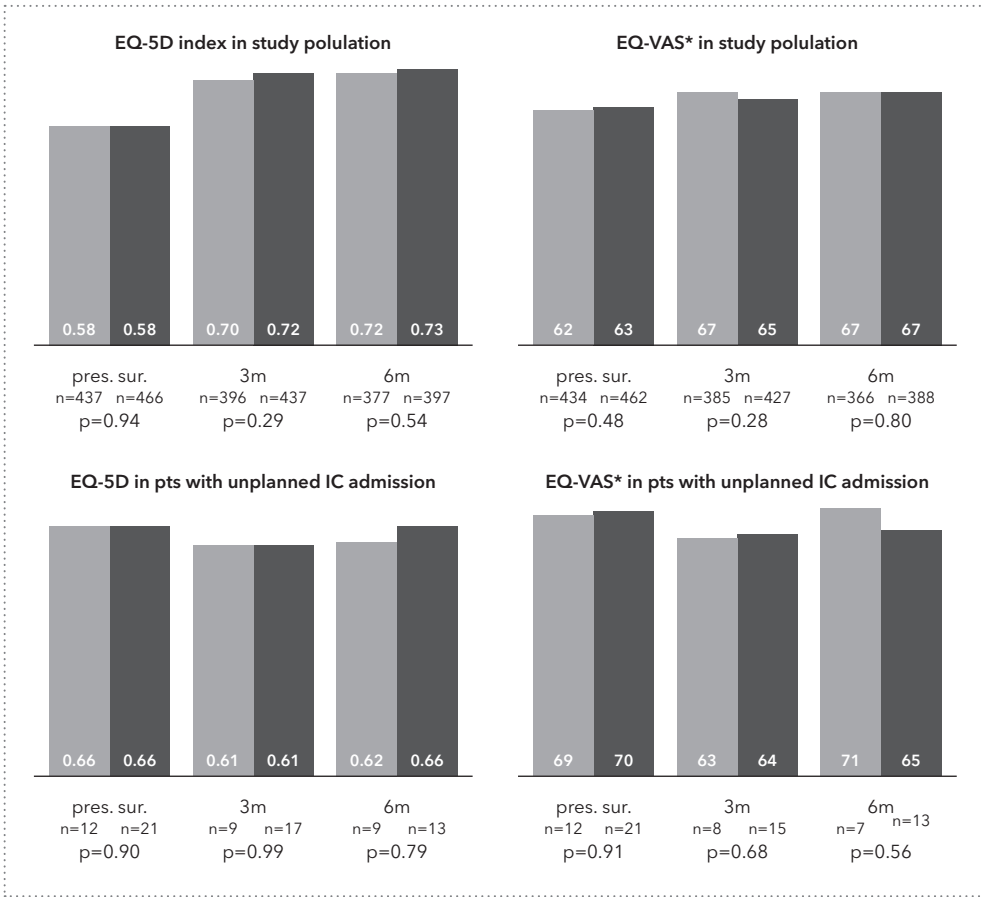

Figure 2 **EQ-5D and VAS mean scores of surgical patients**

Period 1, before implementing the rapid response system
Period 2, after implementing the rapid response system
3m 3 months after surgery
6m 6 months after surgery
EQ-5D Euroqol 5, scale −0.33−1
VAS Visual analogue scale 0-100
RRS Rapid response system
Pre-surgery: fixed factors: gender, American Society of Anesthesiologists' physical status (ASA-PS), covariates: age at admission.
Following surgery: fixed factors: gender, ASA-PS, covariates: age at admission, planned intensive care length of stay not because of a serious adverse event, EQ-5D dimension pre-surgery
*Not all patients filled in the VAS score.

Discussion

We conclude that the implementation of an RRS does not result in a clinically relevant improvement of HRQOL as measured with the EQ-5D and EQ-VAS in patients at 3 and 6 months following major surgery. It is unlikely that the slightly less deterioration in period 2 regarding 'mobility' and 'usual activities' dimensions, which may enable patients to more actively participate in social life, can be attributed to the implementation of the RRS.

The lack of effect on HRQOL may partly be explained by the fact that our RRS was not fully mature. In particular, MET consults were absent or delayed in 50% prior to an SAE, even though abnormal vital indicators were observed[7]. Furthermore, the percentage of included patients who experienced one or more unplanned ICU admissions in period 1 and 2 was considerably low: 2.8% and 4.5%, respectively. The number of unplanned ICU admissions could, therefore, not substantially influence the mean HRQOL scores.

Comparison of HRQOL in the subset of patients with an unplanned ICU admission also showed no improvement after RRS implementation. These results are in line with our original study on the effects of an RRS on SAEs where we showed no decrease in the Acute Physiology and Chronic Health Evaluation (APACHE) II score at admission to the ICU after RRS implementation, indicating that patients were not referred to the ICU in an earlier stage of illness[7].

Our choice to use the EQ-5D as a measure for HRQOL could be questioned, as Brazier et al. (2004) showed a ceiling effect in the EQ-5D in comparison with the short form 6 dimensions (SF-6D) instrument[14]. This ceiling effect may partially explain the lack of effect in our study because 'no problems' were reported in both periods in 25% to 50% of the EQ dimensions at pre-surgery, making improvement on those scores impossible. However, Brazier et al. (2004) also showed that the SF-6D, compared to the EQ-5D, differentiates less accurately when patients experience severe health problems, which was the case for a considerable part of our study population[14]. Moreover, a comparative review of seven generic HRQOL instruments shows no uniformly 'best' or 'worst' performing instrument. The choice of the instrument should be driven by the purpose of the measurement[15]. We used the EQ-5D because the instrument is short and user friendly, which was important since a part of our study population was severely ill. The EQ-5D takes respondents about 7 minutes to complete. We believe, however, that measuring HRQOL with another generic instrument would have yielded similar results.

The most important explanation for our lack of effect is most likely that other factors had a larger influence on HRQOL than merely the implementation of an RRS. We found

that pre-surgery HRQOL and ASA-PS were strongly associated with HRQOL following surgery. Similarly, another study showed that HRQOL strongly associates with diagnostic categories[16]. Associations between HRQOL and these factors may have abated the influence of the RRS implementation on HRQOL. Therefore, the question arises if HRQOL is an adequate measure to assess the influence of an RRS.

EQ-5D and EQ-VAS outcomes showed slightly different patterns. Even though the EQ-VAS scores are predictable from the EQ-5D scores, other group variables also contribute to the EQ-VAS score, such as psychological disposition, age, education and clinically-important distress. These variables explain the differences between the EQ-5D and EQ-VAS outcomes[17].

To our knowledge, this is the first study evaluating the influence of an RRS on HRQOL in patients 3 and 6 months following surgery. We conducted a cohort study before and after RRS implementation. Confounders other than the implementation of an RRS may have biased the results. However, no major changes in surgical procedures or ward policy were implemented during the study period. The pre-surgery HRQOL enabled us to study the impact of pre-admission HRQOL scores on the HRQOL at 3 and 6 months following surgery, which we considered one of the study's strengths. One may argue that the 6-month follow-up period was too short to evaluate HRQOL improvement in surgical patients. However, improvement was most obvious during the first three months, whereas during the last three months only a slight improvement was observed. Furthermore, a longer observation period usually results in the occurrence of other confounders.

Finally, this study was conducted in one hospital and included only patients with major surgery. Results may therefore be different in other settings and with other study populations.

Conclusions

Implementation of an RRS did not convincingly affect HRQOL outcomes. We question if HRQOL is an adequate measure to assess the influence of an RRS. Pre-surgery HRQOL and ASA-PS scores were strongly associated with HRQOL outcomes following surgery and may have abated the influence of the RRS implementation.

Acknowledgements

The authors would like to thank the students of the bachelor of nursing degree and Ans Rensen, lecturer in the bachelor of nursing degree from HAN, for their contributions in gathering data. We would also like to thank all patients for completing the questionnaires. Finally, we would like to thank Sjef van de Velde for his support in gathering the electronic database information and Janine Liefers for her support in the electronic data management of the questionnaires.

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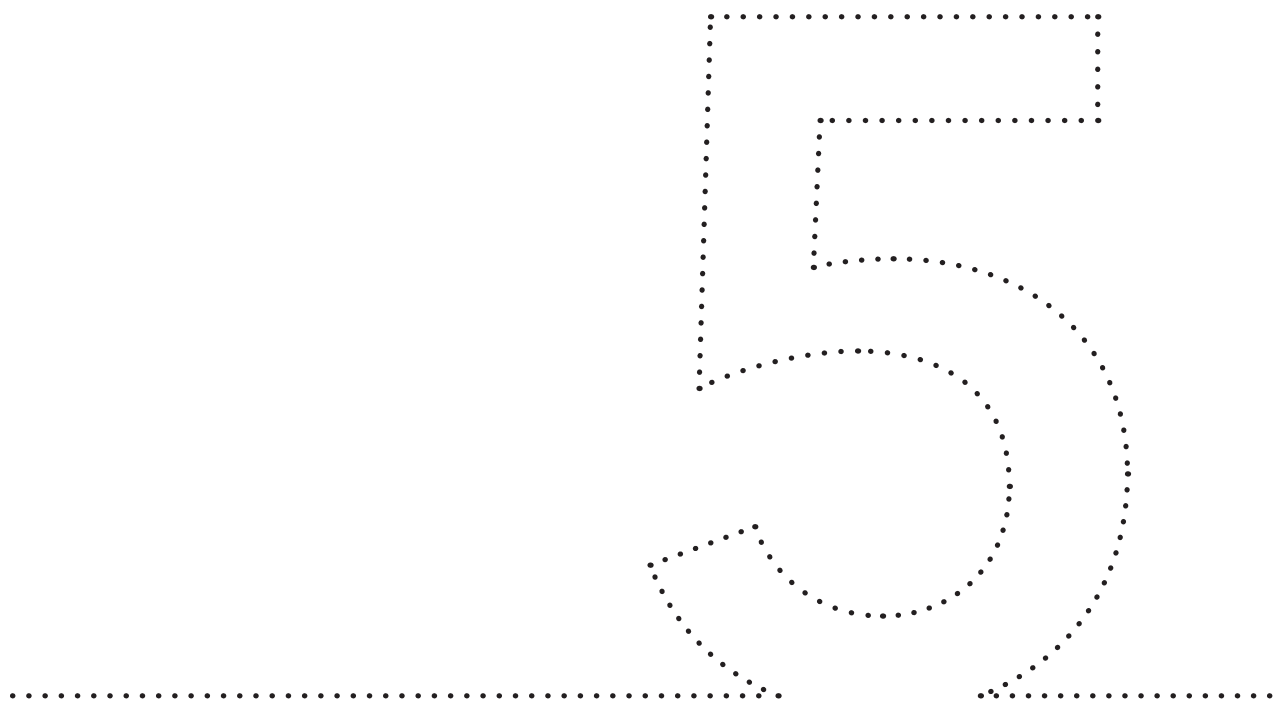
Financial consequences of the implementation of a rapid response system



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Journal of Evaluation in Clinical Practice, accepted for publication March 2014

Abstract

Rationale and aims

Rapid response systems (RRSs) are recommended by the Institute for Healthcare Improvement and implemented worldwide. Our study on the effects of an RRS showed a non-significant decrease in cardiac arrest and/or unexpected death from 0.5% to 0.25%. Unplanned ICU admissions increased significantly from 2.5% to 4.2% without a decrease in APACHE II scores. In this study we estimated the mean costs of an RRS per patient-day and tested the hypothesis that admitting less severely ill patients to the ICU reduces costs.

Methods

A cost analysis of an RRS on a surgical ward, including costs for implementation, a one day training program for nurses, nursing time for extra vital signs observation, medical emergency team (MET) consults and differences in unplanned ICU days before and after RRS implementation. To test the hypothesis we performed a scenario analysis with a mean APACHE II score of 14 points instead of the empirical 17.6 points for the unplanned ICU admissions, including 33% extra MET consults and 22% extra unplanned ICU admissions.

Results

Mean RRS costs were €26.87 per patient-day: implementation €0.33 (1%), training €0.90 (3%), nursing time spent on extended observation of vital signs €2.20 (8%), MET consults €0.57 (2%) and increased number of unplanned ICU days after RRS implementation €22.87 (85%). In the scenario analysis mean costs per patient-day were €10.18.

Conclusions

The costs for extra unplanned ICU days were relatively high but remaining RRS costs were relatively low. The 'APACHE II 14' scenario confirmed the hypothesis that costs for the number of unplanned ICU days can be reduced if less severely ill patients are referred to the ICU. Based on these findings our hospital stimulates earlier referral to the ICU although further implementation strategies are needed to achieve these aims.

Introduction

Patients often show deteriorating vital signs for hours or even days before ending in cardiac arrest or unexpected hospital death[1]. Timely stabilization of vital functions may prevent this. For this purpose, rapid response systems (RRS) were introduced. These systems aim to identify and treat at-risk patients at an adequate level of care during the early phase of deterioration and include the availability of a rapid response team (RRT) to support the ward team[2]. The RRS is highly recommended by the Institute for Healthcare Improvement[3,4] and implemented in many countries. Proceedings of the first international consensus conference on Medical Emergency Teams claimed an outcome benefit of RRSs not only including reduction in cardiac arrests and unexpected deaths but also in ICU- and hospital length of stay and lower costs[2].

Our study on the effects of an RRS showed a non-significant decrease in the effectiveness in cardiac arrest rate and/or mortality[5]. These results are in line with many other studies[6-11]. However, our study in the number of unplanned ICU admissions after implementation (2.5% versus 4.2%), without a decrease in severity of illness (mean APACHE II score17.5 versus 17.6) and median ICU length of stay (LOS) (3.5 days versus 3 days, $p = 0.94$)[5]. These results are in line with the studies of Buist[12] and Karpman[13]. Furthermore, in our study hospital LOS was unchanged[5]. Information on APACHE II scores and ICU/hospital LOS in addition to the number of (un)planned ICU admissions are rarely reported in studies on the effect of an RRS. These outcomes are of influence on hospital costs. Until now, the impact of an RRS on hospital costs has not been studied. Insight in these hospital costs is critical to justify widespread implementation of RRSs.

The aim of this study was to estimate the costs of an RRS. Firstly, we determined the mean costs of the RRS per patient-day. Secondly, by means of a scenario analysis, we explored the hypothesis that an increased number of unplanned ICU admissions with less severely ill patients results in a reduction of the RRS costs per patient-day.

Methods

The need for informed consent was waived by the Medical Ethics Committee of district Arnhem-Nijmegen, CMO-nr.: 2005/310. We compared costs before and after RRS implementation. For this we used data from our before-after study published previously[5]. In brief, the before study (period 1) was conducted for one year, the after study (period 2)

during two years. The RRS was implemented for four months. We included patients who stayed in the surgical ward for ≥72 hours after major general surgery. There were 1376 patients in period 1 and 2410 patients in period 2.

Before introduction of the RRS, consultation of a physician after observing abnormal vital signs was left to the discretion of the attending nurse. Vital signs were not routinely recorded three times daily, and oxygen saturation and respiratory rate were not included in the standard observation protocol. The RRS included the introduction of a medical emergency team (MET) and the use of a single-parameter track and trigger system. The MET was a physician-led team including an intensivist and a critical care nurse and was accessible 24/7. We used a 2-tiered MET calling procedure. In the first tier, nurses were expected to observe the patient with the use of the early warning score (EWS) at least three times daily. Nurses called the ward physician immediately if one of the EWS criteria was met, that is, respiratory rate <8 or >30 per minute, oxygen saturation <90%, systolic blood pressure <90 or >200 mm Hg, heart rate <40 or >130 per minute, a decrease of two points in the eye, motor, verbal (EMV) score, or if the nurse felt worried about the patient's condition[12]. The ward physician had to evaluate the patient at the bedside within 10 minutes. In the second tier the ward physicians activated the medical emergency team (MET) immediately if a serious situation existed or if the patient did not stabilize after an initial intervention.

Cost analysis

The analysis was performed from a health care perspective where only direct medical costs related to the RRS were included. All unit costs were converted to 2009 prices using the Dutch consumer price index, statistics Netherlands[14]. Prices for personnel and ICU costs were retrieved from the Dutch guideline for cost analyses in health care[15].

Mean RRS costs per patient-day

We categorized the costs of an RRS into costs for implementation and maintenance, training, nursing time spent on extended observations of vital signs, MET consults, and differences in the number of unplanned ICU days before and after RRS implementation. Difference in hospital length of stay (LOS) was not included in this calculation since this indicator did not change after RRS implementation (median 7, IQR 5-13 versus median 7, IQR 5-13)[5]. A patient-day was defined as a day in the hospital, including the day of admission and discharge. An unplanned ICU day was defined as a day in the ICU caused by an unplanned

ICU admission from the surgical ward, including the day of admission and discharge.

Costs

Table 1 shows the RRS implementation and maintenance costs made for the surgical ward. For a specification of these costs see Table 2. Table 3 shows a specification of the training costs. Table 4 shows the nursing time spent on extended observations of vital signs per admitted patient. These costs were based on differences between the daily observation time in period 1 and 2. To assess the nursing time needed to observe patients' vital signs, we observed four nurses during vital sign measurements in 16 patients.

The cost of one MET consult was €129.50; 1 hour for an intensivist (€103 per patient-related hour) and 0.75 hour for an intensive care nurse (€30.50 per hour).

The costs of an ICU day and ward day included costs for medical specialists, nurses, material, food and hotel facilities, drugs, housing, overhead and equipment[15]. The extra costs for an ICU day were €1608; calculated as daily ICU costs minus daily ward costs (€2183 - €575). Mean hospital costs per patient-day concerned the mean of the daily ward costs and daily unplanned ICU-day costs.

Table 5 shows the formulas for the calculation of the differences in the mean costs per patient-day before and after RRS implementation. Differences in unplanned ICU days were based upon the ratio of unplanned ICU days per 1000 hospital days before and after RRS implementation (0.12 versus 0.26 respectively).

'APACHE II 14' Scenario

In our effect study, we found a mean APACHE II score of 17.6 for unplanned ICU admissions[5] . Since we found an absent or delayed MET consult in 50% prior to an adverse event we expect that it will be possible to increase the MET consults making earlier ICU referrals possible. In the scenario analysis, we hypothetically lowered the mean APACHE II score to 14. For this, a Monte Carlo simulation approach was used. This method randomly draws APACHE II scores from a distribution based upon a preset mean of 14 and a standard deviation (SD) set on 6.1, based on the SD found in our effect study[5]. The APACHE II score range was set from 0 to 48; this range was derived from the hospital ICU database, period 2004-2011. Subsequently, the ICU LOS for each of the 10,000 simulated APACHE II scores was added into the database. This provides a mean ICU-LOS with SD based upon a mean APACHE II score of 14.

We assumed that to achieve a mean APACHE II 14 score for unplanned ICU admissions from the ward, ICU referral by the MET should occur in 80% of the consulted patients

instead of 60% found in our effect study[5]. Our effect study shows that 65 of the 100 unplanned ICU admissions were preceded by one or more MET consults. We therefore added 22 (22%) unplanned ICU admissions (80/60*65) to the empirical number of 100 unplanned ICU admissions. Furthermore, in the optimal situation, the MET should be consulted in all patients prior to the unplanned ICU admission from the ward. In our effect study 35 of the 100 unplanned ICU referrals were without prior MET consult(s). As mentioned before, we assumed that in 80% of the MET consults the patient should be referred to the ICU. This would result in 44 (33%) extra MET consults (35/0.8) in addition to the 134/2410 empirical MET consults (73 MET consults per 1000 admissions in the 'APACHE II 14' scenario compared to the empirical 56 MET consults per 1000 admissions).

Results

Mean RSS costs per patient-day

Mean RRS costs were €26.87 per patient-day; implementation and maintenance €0.33 (1%), training €0.90 (3%), nursing time €2.20 (8%), MET consults €0.57 (2%) and extra unplanned ICU days €22.87 (85%). Mean hospital costs per patient-day were €594. Costs increaded with €26.87 to €621 (4.5%) after RRS implementation.

In the 'APACHE II 14' scenario we added one-third extra MET consults and one-fifth extra ICU admissions. Mean RRS costs per patient-day were reduced with €16.69 (62%) to €10.18; MET costs increased with €0.19 to €0.76 and costs for extra unplanned ICU days decreased with €16.90 to €5.99. Details are shown in Table 6.

Table 1 **RRS implementation and maintenance costs surgical ward* (in €)**

	Total	Number of wards	Costs surgical ward	Costs spread over ten years = per year*	Surgical ward costs 2 years**
Constructing of an implementation plan	7496	28	268	27	54
Extra materials ICU	22889	7	3270	327	654
Extra materials surgical waward	9760			976	1952
RRS coordination surgical ward, yearly	1568				3136
RRS continuation surgical ward, yearly	2050				4100
Total					9896

* For specification see Table 2
ICU Intensive care unit
RRS Rapid response system
* One-off costs were spread over ten years
** Patients were included during a period of two years

Table 2 **Specification of implementation costs**

Items	Time and materials	Subcosts	Costs
Constructing an implementation plan	Steeringgroup 3 meetings of 2 hours		
	3 physicians,	1296	
	3 nurses	549	
	MET workgroup 3 meetings of 2 hours		
	3 physicians	1296	
	3 nurses	549	
	EWS workgroup 3 meetings of 2 hours		
	2 physicians	864	
	5 nurses	915	
	Diverse e.g. kick off meeting, visiting conferences	2000	
	Total		€7,496
Extra materials ICU	MET car	22889	
	Total		€22,889
Extra materials ward*	2 oxygen meters à 80	160	
	4 dynamaps à 2400	9600	
	Total		€9,760
RRS coordination ward*	1 nurse, 1 hour weekly	1568	
	Total		€1,568
RRS continuation ward*	10 meetings of 1 hour yearly		
	2 nurses	610	
	2 physicians	1440	
	Total		€5,020

MET Medical emergency team
EWS Early warning score
ICU Intensive care unit
ICU Intensive care unit
RRS Rapid response system
costs for one year
*surgical ward
physician €72 per hour
nurse €30.50 per hour

Table 3 Training costs

Items	Time and Materials	Costs
Development	4 nurses, total 35 h, 1 intensivist 4 h	1,478
Material	Syllabus, EWS cards, posters	1000
Overhead	Nurse, 10 h	305
Teachers	2 Intensive care nurses 4*8 h=64 h, 1 intensivist 4*8=32 h	4,256
Nursing training time	83 ward nurses*8 h= 664 h	20,252
Total		€27,291

h Hour
EWS Early warning score
physician €72 per hour
nurse €30.50 per hour

Table 4 Nursing time spent on observation vital signs

	Observations P1	Extra observations P2	Extra time (sec)	Days*moment*time	Total time (sec)
1th and 2nd day after surgery	3 times HF/BP	RR/0_2/EMV	35	2*3*35	210
10,6 other days	2 times HF/BP	RR/0_2/EMV	35	10.6*2*35	742
	1 time no observations	RR/0_2/BP/HF/EMV	220	10.6*220	2332
Nursing time in seconds per admission					3284
Nursing time in hours per admission					0.91

P1 Period 1
P2 Period 2
RRS Rapid response system
sec Seconds
HF Heart frequency
BP Systolic blood-pressure
RR Respiratory rate
O2 Oxygen saturation
EMV Eye, motor, verbal

Observation included hand washing and transfer between patient rooms.
In period 1, systolic blood pressure and heart rate were routinely observed three times daily, during two days following surgery. On the other days these vital signs were routinely observed two times daily.
In period 2, respiratory rate, oxygen saturation, systolic blood pressure, heart rate, and the eye, motor, verbal (EMV) score were observed three times daily throughout admission.

Table 5 Calculation formulas mean RRS costs per patient day

Implementation and maintenance
$\frac{\text{implementation costs}}{\text{patient days P2}} = \frac{9896}{30298} = €0.30$
Training
$\frac{\text{training costs}}{\text{patient days P2}} = \frac{27291}{30298} = €0.90$
Nursing time spent on extended observation of vital signs
$\frac{\text{extra nursing time per admission}}{\text{mean LOS}} * \text{costs nurse hour} = \frac{0.91 \text{ hours}}{12.6} * 30.5 = €2.20$
MET consults
$\frac{\text{MET consults}}{\text{patient days P2}} * \text{costs MET consult} \frac{134}{30298} * 129.5 = €0.57$
Differences unplanned ICU costs P2 compared to P1
$\frac{\text{unplanned ICU days P2}}{\text{patient days P2}} - \frac{\text{unplanned ICU days P1}}{\text{patient days P1}} * \text{extra costs ICU day} = \frac{794}{30298} - \frac{194}{16186} * 1608 = €22.87$
Scenario MET consults
$\frac{\text{scenario MET consults}}{\text{patient days P2}} * \text{costs MET consult} = \frac{178}{30298} * 129.5 = €0.76$
Scenario differences unplanned ICU costs, scenario compared to P1
$\frac{\text{scenario unplanned ICU days}}{\text{patient days P2}} - \frac{\text{unplanned ICU days P1}}{\text{patient days P1}} * \text{extra costs ICU day} = \frac{476}{30298} - \frac{194}{16186} * 1608 = €5.99$

RRS Rapid response system
MET Medical emergency team
ICU Intensive care unit
P1 Period 1
P2 Period 2
* *Training costs were only made for the ward personnel of the surgical ward and this initial training was only given during the introduction of the RRS.*

Table 6 Mean RRS costs per patient day (in €)

	Empirical	%	Scenario	%
Implementation and maintenance	0.33	1.2	0.33	3.2
Training	0.90	3.3	0.90	8.8
Nursing time spent on extended observations of vital signs	2.20	8.2	2.20	21.6
MET consults	0.57	2.1	0.76	7.5
Differences unplanned ICU days P2/scenario compared to P1	22.87	85.1	5.99	58.8
	26.87	100	10.18	100

RRS Rapid response system
MET Medical emergency team
ICU Intensive care unit
P2 Period 2
P1 Period 1

Discussion

We estimated the mean costs of the RRS per patient-day and explored the costs of referring patients to the ICU with a mean APACHE II score of 14. Mean RRS costs were €26.87 per patient-day. The major part of the costs, namely 85%, was caused by the increased number of unplanned ICU-days after RRS implementation. The scenario analysis showed that lowering the mean APACHE II scores of unplanned ICU admissions to 14 considerably reduced the mean RRS costs per patient-day with 62%, even though one-third extra MET consults and one-fifth extra ICU admissions were added. To our knowledge this is the first study attempting to estimate the effects of an RRS on hospital costs.

Since most of the RRS costs are attributable to unplanned ICU days, which increased notably after RRS implementation, it is worthwhile to explore the reasons for this phenomenon to see if those costs can be reduced without increasing mortality. Studies show an association between MET consult delays and increased unplanned ICU admissions[16,17] or an increase in ICU LOS[18]. When considering that differences in costs between an ICU day and a ward day are €1608, which is equal to the costs of 12 MET consults, it may be cost reducing to consult the MET earlier and more frequent in order to avoid, or to timely refer patients to the ICU. In addition, co-management of the MET in less severely ill patients on the ward may be considered, even though this would need several MET consults for one patient. Further research is needed to measure the empirical effects on the mean costs per patient-day of these options. Our cost-calculation model may be useful to get insight in these costs.

Several aspects of our study need to be discussed. We performed an economic evaluation of the RRS based on cost-effectiveness, however the outcomes were not informative due to the wide confidence intervals. Furthermore, a cost-utility analysis was not possible since we found no effect of an RRS on quality of life[19]. However, we feel that a cost analysis of the RRS will be helpful to decide on next steps to improve the RRS and to monitor its effects on costs. The intermediate outcome 'differences in the number of unplanned ICU days' is informative as it allows us to assess in relatively short time periods whether this intermediate outcome is changing.

In addition, one could argue that 'nursing time for extended observations' and 'extra time from ICU personnel to perform MET consults' should not be calculated as costs because the professionals are present and paid for anyway. However, when ward nurses and the MET team are executing RRS tasks they cannot perform other tasks. Therefore, we

consider calculation of the extra time into costs as justifiable.

In our cost analysis we did not take into account the influence of the MET interventions on costs. To do this, we should also have calculated the intervention costs of the ward physicians and medical specialists before and after RRS implementation. In our present design this was not considered feasible.

We are aware that our outcomes on the main RRS costs per patient-day are difficult to generalize to other (international) settings. However, we believe that our model of cost calculation including 'differences in unplanned ICU days' is also useful in other settings to obtain insight in the RRS costs.

Furthermore, our 'APACHE II 14' scenario analysis was built on several assumptions. However, the calculated mean unplanned ICU LOS was based on empirical data. In our view, we made realistic assumptions for the costs of extra MET consults and extra unplanned ICU admissions. In addition, we did not correct for the possible reduction of costs for avoiding unplanned ICU admissions and unexpected death as an effect of timely MET consults and unplanned ICU referrals of less severely ill patients. Therefore, we consider our scenario analyses as far from optimistic. On the other hand we are aware of the number of assumptions made and consequently we formulated our conclusion in a careful way.

Conclusion

Mean RRS costs per patient-day for implementation and maintenance, training, nursing time for extended observation of vital signs and MET consults were relatively low; costs for the increased number of unplanned ICU days were relatively high. The 'APACHE II 14' scenario confirmed the hypothesis that costs for the number of unplanned ICU days can be reduced if less severely ill patients are referred to the ICU, even though considerably more MET consults and unplanned ICU admissions would be expected. Based upon these findings our hospital stimulates earlier referral to the ICU, although further implementation strategies are needed to achieve these aims.

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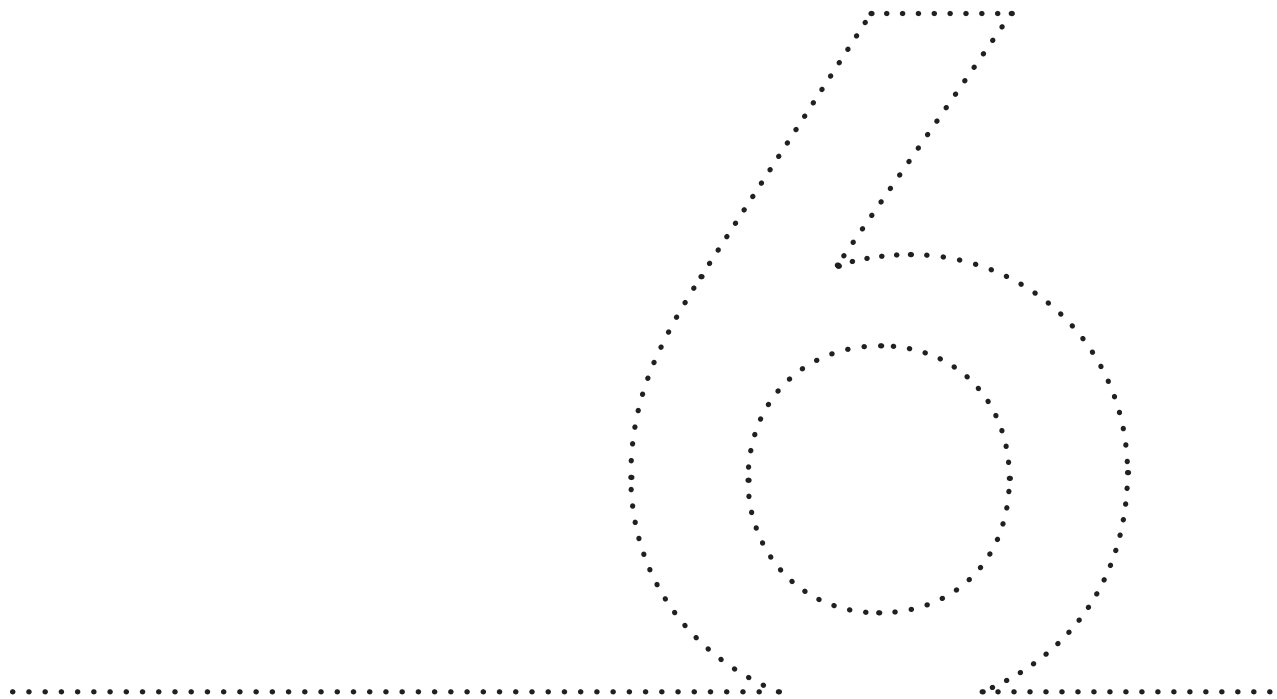
Why is it so difficult to prove that rapid response systems improve patient outcome?

–directions for future research–



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Netherlands Journal of Critical Care 2012; 16 (6) 197-201

Introduction

The implementation of rapid response systems (RRS) is based on the knowledge that deteriorating physiological processes are frequently present for hours or days before clear clinical deterioration is recognized[1,2]. It is assumed that this physiological deterioration is often treatable and that treatment will have greater effect when initiated early[3].

The RRS consists of an afferent limb, including "crisis detection" and "response triggering" and an efferent limb, the rapid response team (RRT)[4].

Even though robust evidence to support the effectiveness of the RRS is lacking[5-10] the system has been implemented worldwide. For example, Dutch hospitals are required to implement a patient safety programme including an RRS before 2013[11].

This article explores the reasons why it is so difficult to prove the effectiveness of an RRS. We discuss the study designs that have been used and the various outcome measures in order to estimate the effects of an RRS. Finally, we make suggestions for future research.

Study design: how to find meaningful control groups?

Study designs used to estimate the effect of a treatment are the randomized controlled trial (RCT) and the non-randomized trial, the so-called quasi experiment[12].

The RCT usually has the most rigorous study design and the advantage of excluding potential bias due to heterogeneity and time trends. To date, the RCT design has been used only twice to estimate the effects of an RRS[13,14]. Both studies used cluster randomization at ward or hospital level, which of course has the disadvantage that e.g. bias due to heterogeneity in standard of care, patient groups, ward staffing ratios and ward staff expertise, cannot be fully eliminated. In addition, with randomization at hospital level, the heterogeneity of RRSs may also influence outcomes. These aspects make it extremely difficult to generalize the outcomes of both studies. Due to heterogeneity, cluster randomization also requires the inclusion of a large number of wards or hospitals. The MERIT researchers estimated that over 100 hospitals were probably needed to show a 30% difference in the composite outcome cardiac arrest, unexpected death and unplanned ICU admissions[14]. Furthermore, since patient safety is an important topic in today's media, increased awareness of the staff to recognize critically ill patients in the control wards or hospitals might have influenced outcomes. While an RCT with randomization on a patient level would be the ideal design to solve these shortcomings, this is practically impossible to achieve.

Due to the aforementioned problems, the quasi experiment is a potential alternative. However, an important drawback of a quasi experiment is the non-randomized comparison

of study groups[12]. The most frequently used quasi-experimental design to estimate the effects of an RRS is the one group before-after design, with the use of historical controls. Almost all those studies have been conducted in single hospitals. Several studies showed a positive effect on mortality[15-20] or incidence of cardiac arrest[15-17,19-23] whereas others found no effect on mortality[24-27] or cardiac arrest[25-28]. Although heterogeneity of patient categories can be partially controlled for, the use of historical control groups offers no way of controlling for other confounding factors, such as improvement in medical treatments and organizational changes[12]. One may therefore question whether the observed changes in outcome are actually due to the RRS.

Finally, systematic reviews and meta-analyses provide an objective method of integrating a number of study results and identifying patterns that otherwise might not have been detected[12]. The drawback of historical control groups was shown in a meta-analysis[9] of quasi-experimental studies as the magnitude of improvement in mortality, cardiac arrests and unplanned ICU admissions in the intervention groups was similar to the control group of the MERIT RCT study. Overall, to date, all reviews and meta-analyses found no or only weak support regarding the effectiveness of an RRS[5-10]. Table 1 shows an overview of the disadvantages of available study designs.

Outcome measures: how to find meaningful outcome measures?

Another reason why it may be difficult or even impossible to show the effectiveness of an RRS is that studies used a variety of outcome measures. The most frequently used outcome measures are the cardiac arrest rate, mortality rate, and number of (unplanned) intensive care unit (ICU) admissions. Unfortunately, the definition of cardiac arrest varies in regard to the type of arrest: cardiac arrest[21] and/or cardiopulmonary arrests[15,17,22,25,26] or cardiac arrest calls[19,28,29]. Also the location of cardiac arrest varies. Most studies used the hospital-wide cardiac arrest rate[7,16,17,19,20,25,26,28,29] thereby including places where the RRS is not active e.g. the operating theatre or the ICU. Others therefore used the out of ICU cardiac arrests[15,23], or cardiac arrests that occurred on the ward[14,22]. Several studies showed a reduction in cardiac arrest rate after the implementation of an RRS. However, this decreased incidence may also be the result of more patients being assigned a do not resuscitate order (DNR)[30-33]. A recent meta-analysis showed that a decline in cardiac arrest rates was not associated with lower hospital mortality[7].

Although the outcome measure mortality appears straight forward, definitions vary among studies. Most studies included all patients who died in the hospital[13,15-17,19,20,23-27,29,30]. Other studies excluded deaths in areas where the RRS was not active e.g. the operating

theatre, the ICU or emergency areas[14,18]. However, ward patients may be referred to the ICU in a late stage of deterioration, and die in the ICU. This was the main reason why in our own study we did not exclude patients who died in the ICU following an unplanned IC admission from the ward[34].

Studies that did show a significant reduction in mortality had a high base line mortality incidence of 10 or more per 1000 admissions[13,16-18,23,25]. In the RCT by Priestley et al., baseline mortality was even 57 per 1000 admissions. It is obvious that a reduction in mortality is difficult to prove in settings with a lower baseline incidence. For example, since the baseline mortality rate in patients without a DNR order in our hospital was 3.6 per 1000, the observed decline of 50% of deaths without a DNR order was not statistically significant (Table 2)[34]. The third frequently used outcome measure is the incidence of unplanned ICU admission. It was hypothesized that implementation of an RRS would decrease the incidence of unplanned ICU admissions due to timely detection and treatment of critically ill patients on the ward[4]. Unfortunately, definitions of ICU admission vary, as some studies included all (planned and unplanned) hospital ICU admissions[17,29] or ICU admissions only from general wards[21] whereas other studies limited inclusion to unplanned ICU admissions[18,35], or unplanned ICU admissions only from the general ward[14,26,36]. Overall, study results are inconclusive; both decreases[17,21,26,36], no effect[14,28,35], and increases in ICU admissions[29,34] have been found. The hypothesis that the RRS decreases the number of unplanned ICU admissions is questionable, as more ward patients may be detected as critically ill and referred to the ICU. This could explain why we found an increased number of unplanned ICU admissions directly from the ward from 2.5% to 4.2% (OR 1.65, CI 1.07-2.55) after implementation of the RRS[34]. Table 3 shows an overview of what we know and do not know about the measured outcomes.

Remaining issues and future research

To reduce the incidence of cardiac arrests and unexpected mortality in ward patients, we need the timely detection and appropriate treatment of deteriorating patients. Research is definitely needed on several topics. First, the accuracy and reliability of the 'track and trigger' systems, since the sensitivity of most current systems is low[32]. Pryterch et al. showed that using a ViEWS score of ≥5 as a trigger would result in a RRT call in 20% of all the observations, which implicates a substantial workload for the RRT team. However, this would only cover 82% of the deaths that would occur within 24 hours after the observation of the trigger[37]. Also the optimal monitoring frequency of the patient's vital signs should be explored in more detail[38].

Second, if treatment is started by the ward staff and/or RRT, it would be interesting to analyze if this treatment is appropriate[39]. For example, a study showed inappropriate treatment by the ward staff, despite an accurate diagnosis in 88% (CI 64%-97%) of all preventable adverse events prior to the RRT call[40]. Our own study showed that 20% of the patients, who were referred to the ICU by the RRT, were initially treated by the RRT on the ward for one or two days[34]. This may partly explain why we did not observe a decrease in the median APACHE II score for unplanned ICU admissions after introduction of an RRS. One other study also reported APACHE scores and found no decrease in scores after introduction of an RRS[29]. Apparently, doctors are reluctant to admit a deteriorating patient to the ICU if they feel that he or she does not fulfil obvious admission criteria, like the need for respiratory or inotropic support.

Third, it is important to define the necessary skills of ward personnel[41] and/or responding personnel[39] in different ward or hospital settings. Other solutions for prompt recognition and treatment of deteriorating patients, rather than implementing a rapid response team, may suffice in particular health care settings[14,42,43]. For example, the Denver Health Medical Centre introduced the afferent arm only, including "crisis detection" and "response triggering". A rapid response team was not introduced since shortage of qualified ward personnel was not a significant issue. Here the patients' designated house staff delivers the majority of care. Introduction of this system resulted in a significant decrease of cardiopulmonary arrests[44].

Fourth, cost-effectiveness studies, including different aspects of recognition and treatment of critically ill patients, would be helpful in choosing the best interventions. For example, if the main results of RRSs would be changes in circumstances of deaths, e.g. more deaths in patients with a DNR order versus deaths in patients without a DNR order, this raises the question whether other measures rather than implementing the complete RRS would suffice.

Finally, non-adherence of the ward staff to set procedures is of serious concern. Even when 'track and trigger systems' and an RRT were implemented, suboptimal documentation of vital signs[14,45] and underuse of the RRT was a frequently reported problem[3,14,26,28,46]. Improvement of the implementation strategy will result in improvement of adherence of staff to procedures and studies on this subject are ongoing[47,48]. From the literature we know that in general, implementation strategies that are used most often target individual professionals (e.g. education, feedback, reminders), whereas strategies targeting social interaction in teams and leadership are very effective but used far less often[49].

Table 1 **Overview of disadvantages of available study designs**

Design	Disadvantages
RCT at patient level	Practically impossible
RCT at ward level	Heterogeneity in - standard care - patient groups - ward staff ratios - ward staff expertise Increased awareness of ward staff on control wards concerning patient safety
RCT at hospital level	Heterogeneity in - standard care - patient groups - ward staff ratios - ward staff expertise - Rapid response system procedures - composition rapid response teams Increased awareness of ward staff on control wards concerning patient safety
Quasi experiment in general	See RCT at ward level
Quasi experiment with the use of historical controls	See RCT at ward level Organizational changes such as ward staff ratios, ward staff expertise Improvement of medical treatment
Meta-analyses and reviews	Heterogeneity

RCT Randomized controlled trial

Table 2 **Deaths before and after implementation of an RRS (per 1000 admissions)**

	Before n=1376		After n=2410		OR	95% CI for OR	p-value
		(%)		(%)			
Death without DNR	5	(0.36)	4	(0.17)	0.42	0.11–1.59	0.200
Death with DNR	9	(0.65)	19	(0.79)	1.05	0.46–2.40	0.900

ICU Intensive care unit
QR Inter-quartile range
LOS Length of stay in days
OR Odds ratio
* Logistic regressions adjusted for age, gender and ASA
CI Confidence interval

Table 3 **Overview of what we know and not know about measured outcomes**

Outcome	What do we know	What do we not know
Cardiac arrest	Unclear: several before-after studies found a positive effect, other studies, including one RCT at hospital level, found no effect.	Was the outcome influenced by… - organizational changes and/or improvement of medical treatment - (some definitions) cardiac arrest calls without resuscitation - (some definitions) cardiac arrest in places where the RRS was not operating? - changes in DNR order policy
Mortality	Unclear: several before-after studies and one RCT on ward level showed a positive effect, other studies, including on RCT at hospital level, found no effect.	Was the outcome influenced by… - heterogeneity between wards? - organizational changes and/or improvement of medical treatment? - (some definitions) mortality in places where the RRS was not operating? - (when defined as deaths without a DNR order) an increase of deaths with a DNR order? Did the outcome… - (some definitions) exclude patients who died on the ICU after an unplanned ICU admission?
ICU admissions	Unclear: several before-after studies showed a decrease, other studies, including one RCT at hospital level, found no effect, and some studies found an increase in ICU admissions.	Was the outcome influenced by… - organizational changes and/or improvement of medical treatment? - (some definitions) unplanned ICU admissions from places where the RRS was not operating? - (some definitions) planned ICU admissions on which the RRS has no influence? Is the outcome reliable? - Increase of unplanned ICU admissions could be positive as this may be the result of early detection of critically ill patients and prevent patients from dying

RRS Rapid response systems
DNR Do not resuscitate
ICU Intensive care unit

Conclusion

Lack of adequate study designs and adequate outcome measures make it almost impossible to show the effectiveness of an RRS. Future research should therefore focus on the different aspects of the system, e.g. improvement of 'track and trigger systems' and treatment skills, ways to effectively and efficiently organize the care for critically ill patients in different organizational settings and the improvement of implementation strategies.

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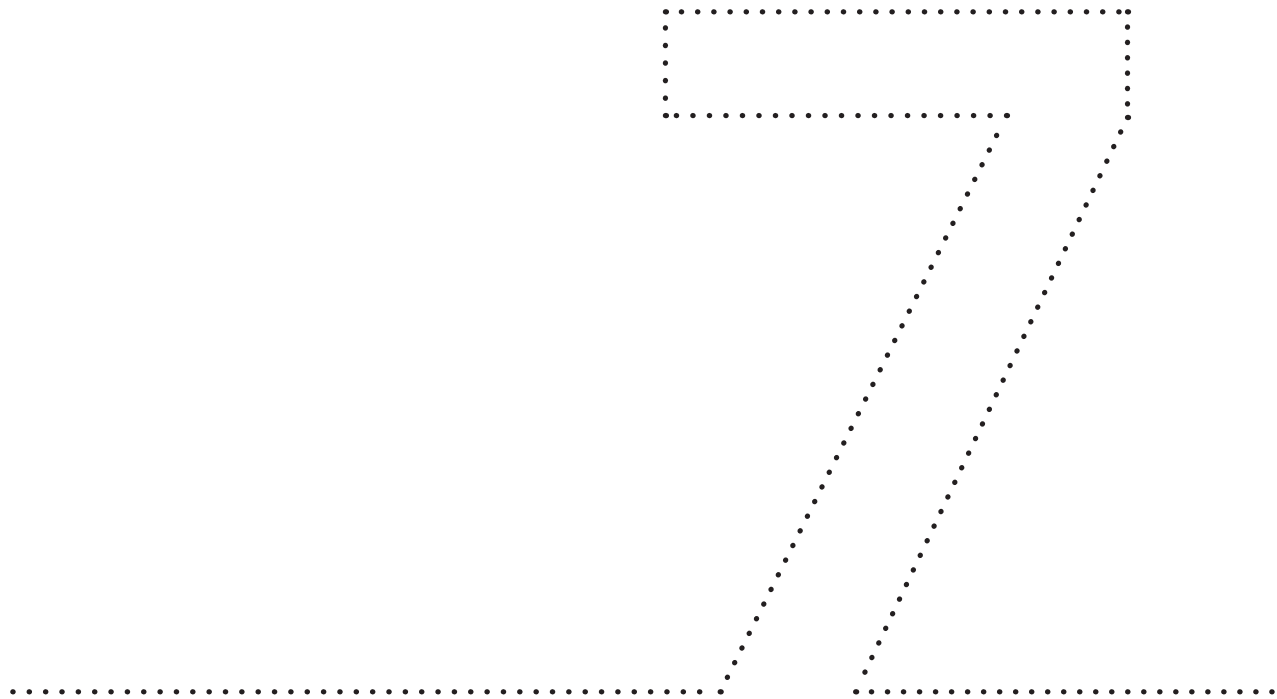
Summary and general discussion



Introduction

The development of Rapid Response Systems (RRS) was based on the hypothesis that timely identification and stabilization of ward patients with unstable vital functions may prevent serious adverse event (SAEs), including cardiac arrest and/or unexpected death[1]. An RRS includes a set of predetermined basic vital functions for the assessment of patients, preferably at a maximum interval of 12 hours[2]. When predefined thresholds are recorded, a protocol for activating adequate help has to be followed. In our study we used a two-tiered calling protocol. In the first tier, nurses had to call the ward physician immediately if a predefined threshold was met. The ward physician had to evaluate the patient at the bedside within 10 minutes. In the second tier, ward physicians had to call the medical emergency team (MET) immediately if a serious situation existed or if the patient did not stabilize after an initial intervention. The MET was a physician-led team, including a critical care physician and a critical care nurse and was accessible 24/7. If the ward physician was unable to visit the patient in time, nurses were expected to call the MET directly.

In this thesis we studied the effect of the RRS on SAEs, health-related quality of life (HRQOL) and hospital costs in surgical patients. In addition we assessed the effect of the implementation strategy on protocol adherence by the ward staff and identified key elements for improvement. Finally, we reasoned why it is so difficult to show effects of an RRS on patient outcomes.

In this chapter we summarize and discuss the study results. Subsequently we describe the implications of our findings for clinical practice and future research.

Summary of study results

The effects of an RRS on the incidence of cardiac arrest and/or unexpected death are described in **Chapter 2.** We showed that the introduction of an RRS on the surgical ward resulted in a 50% reduction of cardiac arrest and/or unexpected death, from 0.5% to 0.25%. However, this decrease did not reach statistical significance. In contrast, the number of unplanned intensive care unit (ICU) admissions increased significantly from 2.5% before the implementation of an RRS to 4.2% after implementation. No significant decrease in the median APACHE II score of unplanned ICU admissions or in the median unplanned ICU length of stay (LOS) was found. Finally we showed that MET calls were absent or delayed for one or two days in over 50% of the SAEs although clear warning criteria were present.

However, from these data we cannot conclude that implementing a RRS is not useful. The study may be underpowered due to the low baseline incidence of cardiac arrest and/or unexpected deaths. Moreover, absent or delayed MET activation may have had a negative impact on the results.

In **Chapter 3** we describe our implementation strategy and its effects on RRS protocol adherence of the ward staff in order to identify key elements for improvement. Our implementation strategy was multi-faceted, including the development of clear objectives; participation and support from key leaders of the medical- and nursing staff; use of a tailored RRS procedure including a two-tiered medical emergency team (MET) warning protocol, a 1-day training program including a before-after knowledge test, obligatory for nurses and voluntary for ward physicians; use of reminders and feedback. After the training program we showed that nurses' knowledge concerning the basic vital functions and the so called early warning score (EWS), was adequate. After implementation, complete EWS recordings were present in 90% of the day shifts, 88% of the evening shifts and 80% of the night shifts. In addition, we analyzed the medical records of patients with an SAE from two days preceding the SAE and the day the SAE occurred. (In)complete EWS recordings were present at least once in 92 of the 101 records; in 91 of those 92 records the EWS was abnormal at least once. In 87% of those events the nurse called the ward physician once or more. After being called by the nurse, the ward physician called the MET once or more in 75%. The ward physician and/or the MET was called with a delay of one or two days in 18% of the SAEs.

We concluded that nurses' observation of the early warning score was acceptable. However, both early warning score recordings in the medical records and warning of the ward physician by the ward nurses and the MET by the ward physicians were suboptimal, resulting in absent or delayed MET calls.

In **Chapter 4** we tested the hypothesis that the RRS system has a positive effect on health related quality of life (HRQOL). We conducted a prospective cohort study in surgical patients before and after implementation of an RRS. HRQOL was measured using the EuroQol-5 dimensions (EQ-5D) and the EQ visual analogue scale (VAS), pre surgery and at 3 and 6 months following surgery.

We found no effect of RRS implementation on the EQ-5D index and EQ-VAS, 3 and 6 months following surgery. This was also true for the subpopulation of patients with the SAE 'unplanned ICU admission'. In an additional analysis we found that pre-surgery HRQOL- and American Society of Anesthesiologists physical status (ASA-PS) scores were strongly associated with HRQOL 3 and 6 months following surgery.

We question if HRQOL is an adequate measure to assess the influence of an RRS, and whether an RRS influences the quality of life after hospitalization at all, since other factors probably are of far more impact on HRQOL.

In **Chapter 5** we studied the costs of an RRS and tested the hypothesis that admitting patients to the ICU with lower APACHE II scores would reduce ICU costs. RRS costs included implementation, training, nursing time for extended vital signs observation, medical emergency team (MET) consults and differences in unplanned ICU days before and after RRS implementation. To test the hypothesis that admitting patients to the ICU with lower APACHE II scores would reduce ICU costs, we performed a scenario analysis. For this we used the mean APACHE II score of 14 points instead of the empirical 17.6 points in patients admitted to the ICU unplanned. In addition, we included 33% extra MET consults and 22% extra unplanned ICU admissions.

The total RRS costs were €26.87 per patient day. Most of the costs, namely €22.87 (85%), were explained by the increased unplanned ICU days after RRS implementation. In the scenario analysis mean RRS costs per patient day were €10.18; costs for unplanned ICU days decreased to €5.99.

We concluded that RRS costs for extra unplanned ICU days were relatively high and remaining RRS costs were relatively low. Scenario analysis suggests that costs can be considerably reduced when patients are admitted to the ICU while less severely ill, even though considerably more MET consults and unplanned ICU admissions would be expected. Finally, in **Chapter 6** we explored the reasons why it is so difficult to show the effectiveness of an RRS. We discussed the study designs that have been used to estimate the effects of an RRS. Randomized controlled trials with randomization on hospital or ward level would require the inclusion of an almost infeasible large number of wards or hospitals, due to heterogeneity in standard of care, patient groups, ward staffing ratios, ward staff expertise etc., etc. An important drawback of a potential alternative, the quasi experiment, is the non-randomized comparison of study groups. Although heterogeneity of patient categories can be partially controlled for, the use of historical control groups offers no way of controlling for other confounding factors, such as improvement in medical treatments and organizational changes.

In addition we discussed the most frequently used outcome measures to estimate the effects of an RRS: cardiac arrest, mortality and unplanned ICU admissions. Several studies showed a reduction in the cardiac arrest rate after implementation of an RRS. However, this decreased incidence may also be the result of more patients being assigned a do not resuscitate (DNR) order[3-6]. A meta-analysis showed an increase in DNR orders and a decline

in cardiac arrest rates which was not associated with lower hospital mortality[7]. Studies that did show a significant reduction in mortality had a high base line mortality of 10 or more per 1000 admissions[8-13]. It is obvious that in our study a reduction in mortality was almost impossible to prove with a baseline incidence of only 3.6/1000 admissions without a DNR order. Lastly, the use of unplanned ICU admissions, based on the hypothesis that the RRS decreases the number of unplanned ICU admissions, is questionable since more ward patients may be detected as critically ill and referred to the ICU.

Discussion

RRSs were introduced worldwide to reduce serious adverse event in acutely ill patients and are intuitively thought to be effective. However, studies showing their effectiveness are not equivocal[17,14-18] . We too were unable to show a positive effect on the rate of cardiac arrest and/or unexpected death. Moreover, we found that implementation of an RRS increased hospital costs, which were to a large extent caused by the increased number of ICU days after RRS implementation. However, we cannot conclude that introduction of a RRS is ineffective for two reasons. First, the low base line incidence of cardiac arrest and/or unexpected death makes it very difficult to prove a significant reduction in these outcome parameters in our hospital. Second, implementation was likely suboptimal since half of the unplanned ICU admissions were not preceded by a MET consult.

Our scenario analysis clearly showed that an increase of unplanned ICU admissions can result in a decrease in the number of ICU days per 1000 patient days, provided that patients are admitted at an earlier stage. Remarkably, only a few studies reported APACHE scores in addition to the number of ICU admissions from the ward[19,20-22]. Karpman and Buist used the same definition for ICU admissions as we did, namely unplanned ICU admissions from wards where the RRS was active and their results were in line with our findings.

We therefore conclude that further implementation strategies should aim at a more intensive use of the MET and a policy to refer less sicker patients to the ICU. To realize this, team oriented education, improvement of track and trigger systems and the development of patient safety bundles are needed. Based on the outcome 'ICU days per 1000 patient days' and process evaluations one may decide if the RRS is effective or that other solutions are preferable to deliver adequate care for the critically ill patient on a particular ward.

Implications for clinical practice and research

Team oriented education

In chapter 3 we reasoned that future implementation strategies should be aimed at the interdisciplinary team to improve protocol adherence. However, training programs for the interdisciplinary ward staff concerning protocol knowledge and inter-disciplinary communication skills alone will probably not suffice, since shared perceptions regarding patient safety norms and behaviors by the ward staff is a premise for successful patient safety interventions[23]. This means that the ward staff should understand the principles of „safe design" including standardization, use of appropriate checklists and learning from mistakes. Furthermore, the ward staff should understand that teams make better decisions with the input from all of the participating disciplines. Elements of the crew resources management (CRM) training[24], may be also useful for ward team training. The program focuses on teamwork, threat and error management and blame free discussion of human mistakes. Furthermore, education should be continuous since several studies identified this as a major factor affecting the use of the MET[25].

Another reason to train the entire team is that literature shows that nurses' uncertainty to call the ward physician increases when they get mixed messages from their leaders, including management, senior medical and nursing personnel, when asking for help[25-27]. Implementation strategies including the team leaders is therefore essential when improving the safety climate[28]. This approach was shown to be effective in a study for improving hand hygiene[28-30]. Future research should focus on the development of patient safety training programs for interdisciplinary ward teams and their effect on SAEs.

In addition, communication skills training of MET personnel should also be considered. Literature shows that communication skills of the MET members is very important for protocol adherence of the ward staff. The MET members should be supportive and behave like colleagues[31] and should never criticize the ward staff for calling the MET[32]. In addition, a formal debriefing procedure should be implemented immediately after the MET consult[33].

Improvement of the track and trigger systems

Another way to optimize the use of the RRS is improvement of the track and trigger systems. Bellomo et al. showed that automated patient monitoring resulted in faster acquisition of vital signs and an improved in-hospital survival in MET call patients[34]. Automated systems may also incorporate laboratory results[35], severity of illness scores, and longitudinal chronic illness burden in order to increase specificity and sensitivity of the track and trigger system[36].

Of special interest is the potential usability of lactate levels since research showed that increased lactate levels may better predict mortality than systolic blood pressure and heart rate[37]. Lactate guided therapy is also useful in early resuscitation of critically ill patients[38]. Research should establish if incorporation of lactate levels may be beneficial in less critically ill ward patients. Likewise promising are programs plotting different patient data against each other into individual specific patterns. Small changes in these patterns which do not reach the common thresholds for deterioration, will allow detection of deterioration in an earlier stage[39]. However, technical innovations are not a guarantee in itself since Tirkkonen et al. recently showed that despite the fact that documentation of vital signs increased with automated patient monitoring, MET calls in case of abnormal vital signs were absent more often compared to traditionally monitored patients[40].

Until better track and trigger systems are developed, we believe that existing track and trigger systems are helpful to improve the care for critically ill patients, provided that the ward staff is aware of their shortcomings. The ward staff should accept that a considerable number of patients having abnormal scores do not always require further assistance besides a thorough review, extra vital signs monitoring and a clear plan in case instability persists. The ward staff should also be aware of the value of the subjective 'worried' criterion. Study results suggest that patients at risk are identified earlier by nursing observation than by vital sign abnormalities[41]. Research on operationalization of the worried criterion and its impact on identifying critically ill patients is ongoing[42]. Last but not least, recent studies showed that patients and their relatives may have a role in triggering the RRS when they feel that the patient is deteriorating[43,44]. However, many patients are unaware of the severity of their clinical condition or are unsure of the significance of their symptoms. Staff should therefore actively seek their views. Inclusion of 'patients and relatives concerns' as a parameter of the worried criterion could promote this dialogue[45]. Involvement of patients and relatives in health care in order to improve safety is also emphasized by international policy[46].

Patient safety bundles

Protocol adherence may further increase when the RRS protocol is easily incorporated in the daily care. The RRS protocol was introduced in the context of the national hospital safety program. Beside the RRS protocol the program includes protocols for prevention of fall accidents, delirium, physical deterioration and malnutrition in older adults; adequate pain management; prevention of adverse drugs events, prevention of central line infections and sepsis treatment [47]. Experience has shown that attempts to design for perfection, commonly

lead to overly complex protocols[48]. Development of one or more 'patient safety bundles' may be helpful. A bundle is a group of several scientifically grounded elements essential to improve clinical outcomes[49]. The ward staff should be involved in the development of 'patient safety bundles' and be allowed to choose a less than perfect, but workable design. Future research should focus on indicating essential elements in 'patient safety bundles'.

Parameters to evaluate the care for the critically ill patient

Since the effectiveness of the RRS has not been proven yet, continuous evaluation with the use of the outcome parameter 'number of ICU days per 1000 patient days' may be helpful to decide what further strategies are needed to improve patient safety and to reduce costs. In our hospital the number of unplanned ICU days per 1000 hospital patient days increased from 0.12 before RRS implementation to 0.26 after RRS implementation. If this number does not decrease after further implementation strategies, other solutions for the care of the critically ill patient rather than maintaining (all elements of) the RRS system should be considered.

Process evaluation is essential since this will give insight into what specific strategies are needed to improve the outcome. We evaluated the adherence to the afferent RRS procedure by retrospective analysis of the medical records of patients with an SAE. Vital sign recording rates and ward physician/MET calling rates following abnormal recordings were estimated during two days preceding an SAE and on the day of the SAE. With this method the afferent limb failure (ALF) indicator, defined as documented warning criteria for which no MET call was triggered[50] can be established. A disadvantage of the ALF is that the method is based on recorded vital signs which are in practice often incomplete[51-54]. The first and foremost step of the RRS is to observe patients' vital signs systematically. Therefore, the number of missing vital signs should always be part of the evaluation method to interpret the data. Furthermore, the 'worried' criterion may be important to recognize the deteriorating patient in an even earlier stage of illness. However, estimation of the influence of the 'worried' criterion is often impossible when reasons for calling are not explicitly documented. The ward staff therefore should be encouraged to document information on this criterion. We also suggest to analyze cardiac arrests, unexpected deaths and unplanned ICU admissions with high APACHE scores to determine if these events were avoidable and if so, to learn from it.

Other solutions

In chapter 6 we discussed other solutions for prompt recognition and treatment of deteriorating patients, depending on factors such as skills of the ward staff, availability of intensive care personnel, patient groups, ward- and hospital facilities, ward staff-patient ratio, etcetera[55-57]. Examples of a simple solution is the regular observation of vital signs and a calling procedure to a ward based response team instead of an intensive care unit based response team[58,59]. In case of abnormal vital signs the ward-nurse, the attending ward-physician and a senior ward nurse immediately form the response team and act on the abnormalities. Implementation of this model showed reductions in cardiac arrests and unexpected deaths, but also in this study, base-line incidence was high. On the other end of the spectrum, a far more intensive model focuses on intervening in an earlier stage of deterioration in order to prevent a crisis[60]. In this model a progressive care unit was established on a surgical ward. Furthermore, an intensivist and a physician assistant joined the ward staff during the daily multidisciplinary ward rounds. With input from the ward staff, the intensivist identified a patient as high- or low risk. High risk patients were referred to the progressive care unit on the ward or to the ICU. Patients on the progressive care unit were observed by the intensivist or the physician assistant at least four times daily. The model was cost saving because of significant reductions in total hospital length of stay and ICU length of stay, despite the incremental costs of the extended ward staffing.

Furthermore, we should be cautious that the MET will not be used as a 'band-aid', obscuring underlying problems such as patients admitted to an incorrect level of care or an insufficient ward nurse-patient or physician-patient staffing ratio. In particular, several studies support a relationship between the nurse-patient ratio and in-hospital mortality[61]. Adequate nurse–patient ratios can lead to better surveillance of the patient, which, along with many other factors, can influence the process of care and lead to better patient outcomes[62].

Finally, after implementation many subsequent modifications are likely to be necessary. Ideally, these modifications should be based on thorough evaluation of the system. We emphasize the need for a RRT coordinator who is responsible for regular evaluation of both outcome and the process of the care. The coordinator should initiate the necessary changes and coordinate communication with the different stakeholders. We realize that implementing an RRS was only the first step. We are ready for the next phase.

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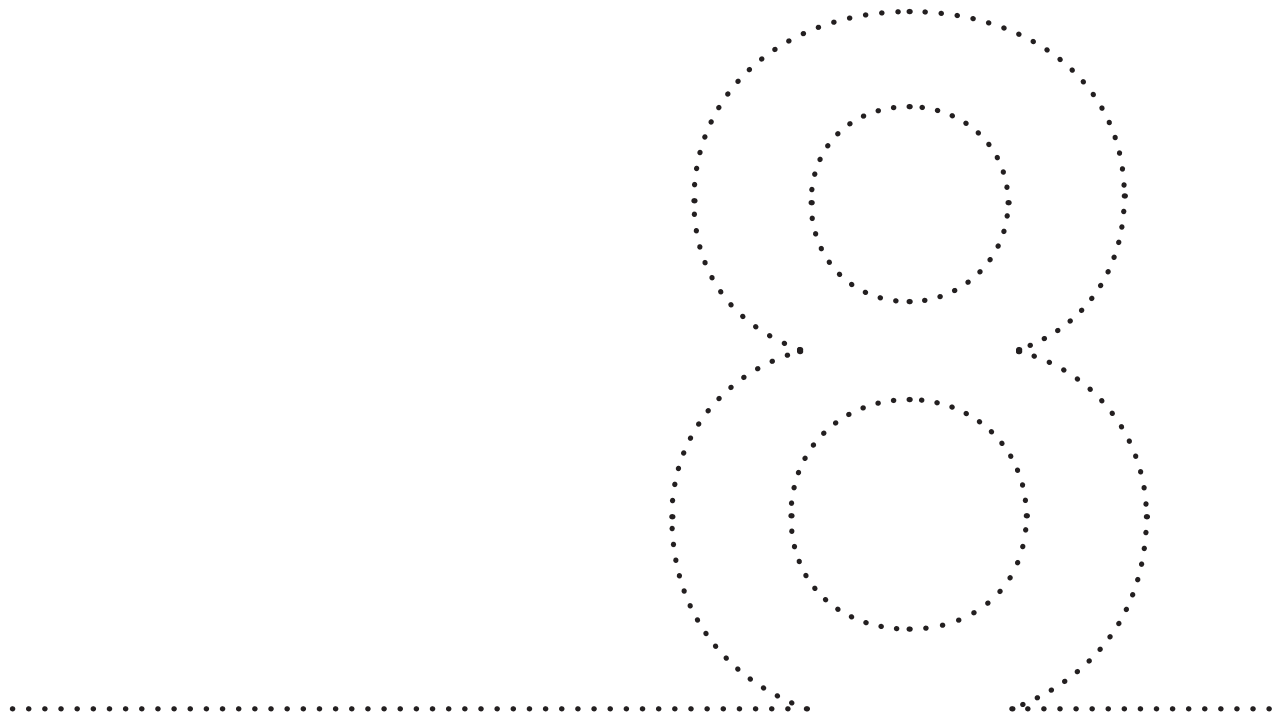
Samenvatting



Samenvatting

Het Spoed Interventie Systeem (SIS) is ontwikkeld vanuit de gedachte dat onbedoelde schade, zoals een reanimatie of onverwacht overlijden, kan worden voorkomen door tijdige herkenning en adequate behandeling van vitaal bedreigde patiënten op de verpleegafdeling. Het SIS bestaat uit drie componenten: een signaleringssysteem voor herkenning van de vitaal bedreigde patiënt, een Spoed Interventie Team, met expertise in het behandelen van de vitaal bedreigde patiënt, en een evaluatiesysteem. Het signaleringssysteem bestaat uit een aantal vitale parameters met vastgestelde afkappunten voor normaalwaarden. De vitale parameters dienen op regelmatige tijden bij de patiënt te worden geobserveerd. Bij observatie van abnormale vitale parameters treedt een protocol in werking om adequate hulp te organiseren. Indien het Spoed Interventie Team wordt geleid door een arts, zoals in ons geval, wordt gesproken van een Medical Emergency Team (MET).

In onze studie werden iedere acht uur de vitale parameters van patiënten op de chirurgische afdeling geobserveerd en geregistreerd door verpleegkundigen. Na observatie van abnormale vitale parameters, of als de verpleegkundige zich ongerust voelde over de patiënt, werd een tweefasen oproepprotocol gestart. In de eerste fase waarschuwde de verpleegkundige onmiddellijk de dienstdoende arts. De arts werd binnen 10 minuten bij de patiënt verwacht om de situatie te evalueren. In de tweede fase waarschuwde de arts onmiddellijk het MET als de patiënt acuut vitaal bedreigd bleek of als de patiënt na een initiële interventie niet stabiliseerde. De verpleegkundige belde het MET rechtstreeks als de dienstdoende arts niet in staat was om de patiënt tijdig op de afdeling te beoordelen. Het MET bestond uit een intensive care verpleegkundige en een intensivist en was 24/7 bereikbaar.

Dit proefschrift had tot doel om bij chirurgische patiënten de effecten van het SIS op het voorkomen van onbedoelde schade, de gezondheid gerelateerde kwaliteit van leven (KvL) en de ziekenhuiskosten per patiënt-dag vast te stellen. Daarnaast werd het effect van de implementatiestrategie op protocolopvolging door de afdelingsstaf in kaart gebracht om elementen voor verbetering te identificeren. Tot slot is beargumenteerd waarom de effecten van een SIS op het niveau van patiënten uitkomsten moeilijk zijn vast te stellen.

Nadat we in hoofdstuk 1 zijn ingegaan op de uitgangspunten van het SIS en de achtergrond van deze studie, beschrijven we in hoofdstuk 2 de effecten van een SIS op het voorkomen van onbedoelde schade, gedefinieerd als reanimatie en/of onverwacht overlijden en ongeplande intensive care (IC)-opname. We voerden een voor-na studie uit bij patiënten die

na de chirurgische ingreep minimaal 72 uur op de afdeling verbleven. De introductie van het SIS resulteerde in een afname van reanimaties en/of onverwacht overlijden met 50%: van 0,5% naar 0,25%. De afname was echter niet statistisch significant. Daartegenover nam het aantal ongeplande IC- opnames significant toe: van 2,5% naar 4,2%. Echter, de mediane APACHE II score bij de ongeplande IC-opnames en de mediaan van het aantal ongeplande IC-dagen per opname daalden niet. Tot slot vonden we dat bij 50% van de patiënten, bij wie voorafgaande aan de onbedoelde schade abnormale vitale parameters waren geobserveerd, het MET niet, of met een vertraging van één tot twee dagen werd opgeroepen. Toch konden we op basis van deze uitkomsten niet concluderen dat implementatie van het SIS ineffectief is. Onze studie was waarschijnlijk underpowered omdat de uitkomstmaten 'reanimatie' en 'onverwacht overlijden 'een lage baseline incidentie hadden. Bovendien werd het oproepprotocol suboptimaal uitgevoerd waardoor de effecten van het SIS beperkt bleven.

In hoofdstuk 3 beschrijven we de implementatiestrategie van het SIS en de effecten hiervan op de opvolging van de SIS-protocollen door de afdelingsstaf. De doelstelling van deze studie richtte zich op het opsporen van kernelementen voor verbetering. Wij ontwikkelden in samenwerking met sleutelfiguren van de medische- en verpleegkundige IC- en afdelingsstaf verschillende, op maat gemaakte implementatiestrategieën. Deze richtten zich op het formuleren van duidelijke doelstellingen; het tweefasen oproepprotocol; een eendaags trainingsprogramma, verplicht voor verpleegkundigen en vrijwillig voor artsen, met een begin- en een eind kennistoets; en tot slot het gebruik van reminders en feedback. Na het trainingsprogramma was de kennis bij verpleegkundigen over de vitale parameters en de normaalwaarden van het signaleringssysteem, de zogenaamde 'Early Warning Score (EWS)' adequaat. Na implementatie van het SIS was op de patiënt-daglijsten in 90% van de dagdiensten, 88% van de avonddiensten en 80% van de nachtdiensten een volledige EWS gerapporteerd. In 92 van de 101 medische dossiers van patiënten met een onbedoelde schade werd in de twee dagen voorafgaande aan de onbedoelde schade tot en met de dag dat de onbedoelde schade zich voordeed, minimaal één (in)complete EWS gerapporteerd. In 91 van de 92 gevallen was de EWS minimaal één keer abnormaal en in 87% belde de verpleegkundige minimaal één keer de dienstdoende arts. Na te zijn gewaarschuwd door de verpleegkundige belde de dienstdoende arts in 75% van de gevallen het MET. De dienstdoende arts en/of het MET werd in 18% gebeld met een vertraging van één of twee dagen. Wij concludeerden dat de observatie van de vitale parameters door de verpleegkundigen acceptabel was. Echter, zowel de rapportage van de EWS in de medische dossiers als ook het waarschuwen van de dienstdoende arts door de verpleegkundigen en het oproepen van het MET door

de dienstdoende arts waren suboptimaal waardoor het MET niet, of met vertraging, werd ingeschakeld. Wij concludeerden dat de implementatiestrategie, die primair op de verpleegkundigen was gericht, in de toekomst ook op de medische afdelingsstaf gericht zou moeten zijn.

In hoofdstuk 4 onderzochten we de hypothese dat het SIS een positief effect heeft op de gezondheid gerelateerde kwaliteit van leven (KvL). In een prospectieve cohortstudie hebben wij bij de patiënten voorafgaande aan-, en 3 en 6 maanden na de chirurgische ingreep de gezondheid gerelateerde KvL gemeten. De studie werd voor- en nadat het SIS was geïmplementeerd uitgevoerd. De gezondheid gerelateerde KvL werd gemeten met het EuroQOL-5 dimensies (EQ-5D) meetinstrument en de EQ visueel analoge schaal (VAS). We vonden geen effect van het SIS op de EQ-5D index en de EQ-VAS score 3 en 6 maanden na de chirurgische ingreep. Wij concludeerden dat de gezondheid gerelateerde KvL geen adequate maat is om het effect van een SIS te meten; onze studie suggereerde dat andere factoren van grotere invloed waren op de gezondheid gerelateerde KvL.

In hoofdstuk 5 hebben wij de kosten van een SIS per patiënt-dag in kaart gebracht. Daarnaast testten we de hypothese dat de kosten voor ongeplande IC-opnames omlaag gebracht kunnen worden door weliswaar meer, maar minder ernstig zieke patiënten met een lagere APACHE-score naar de IC te verwijzen. SIS kosten omvatten de kosten voor implementatie; training; de extra tijd die verpleegkundigen nodig hebben voor het uitgebreider observeren van de vitale parameters; MET-consulten; en het verschil in ongeplande IC-dagen voor- en na SIS implementatie. Om onze hypothese te testen werd een scenarioanalyse uitgevoerd. In het scenario hebben we de gemiddelde APACHE-score op 14 gesteld, in plaats van de empirisch vastgestelde gemiddelde APACHE-score van 17,6. Daarnaast hebben we 33% extra MET-consulten en 22% extra ongeplande IC-opnames in het scenario opgenomen. Wij berekenden dat de SIS kosten €26,87 per patiënt-dag bedroegen. De meeste kosten, namelijk € 22,87 (85%), konden worden verklaard door het toegenomen aantal ongeplande IC-dagen per 1000 patiënt-dagen na implementatie van het SIS. In het scenario daalden de gemiddelde SIS kosten tot €5,99 per patiënt-dag. Wij concludeerden dat de SIS-kosten voor de extra ongeplande IC-dagen relatief hoog, en de overige SIS-kosten relatief laag waren. Het scenario suggereerde dat de kosten behoorlijk gereduceerd kunnen worden als minder ernstig zieke patiënten ongepland naar de IC worden verwezen, ook als dit een aanzienlijke toename van het aantal MET-consulten en ongeplande IC-opnames met zich mee brengt.

In hoofdstuk 6 beschrijven we de redenen waarom in onderzoek de effectiviteit van een SIS moeilijk is aan te tonen. Op de eerste plaats bediscussieerden we de gangbare

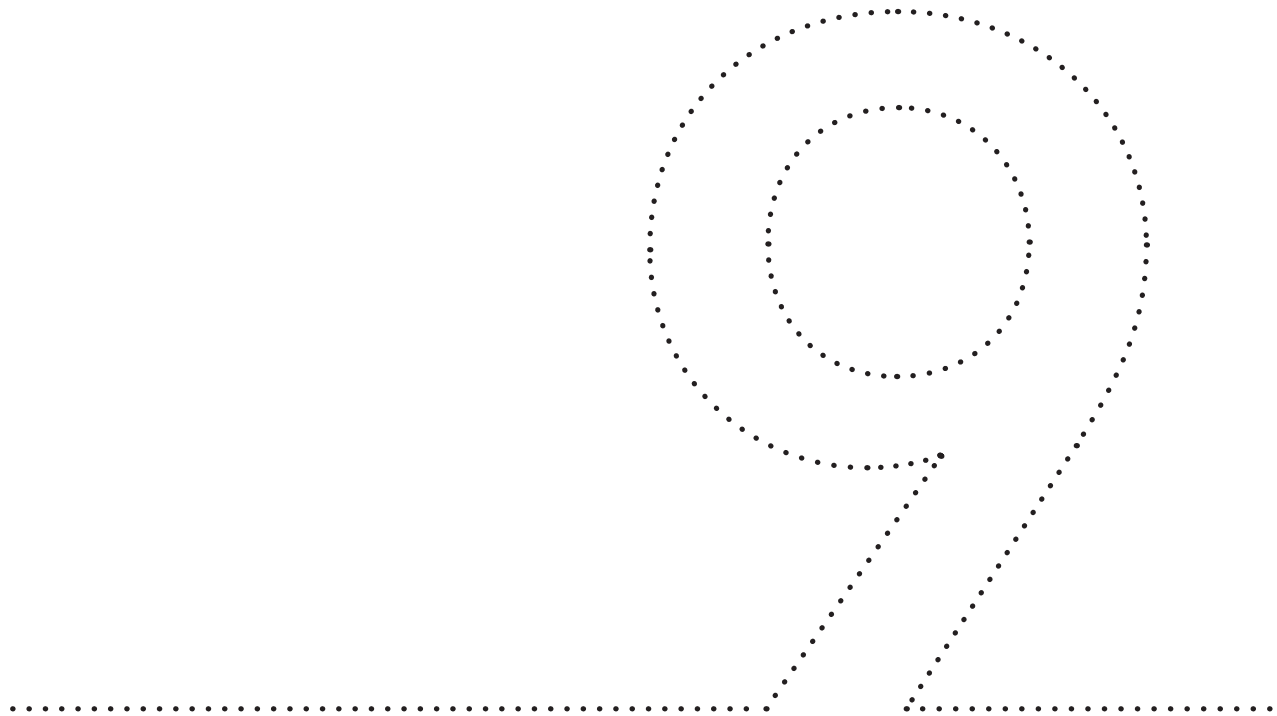
studiedesigns die worden gebruikt om de effecten van het SIS vast te stellen. Een gecontroleerde interventiestudie, met randomisatie op ziekenhuis- of afdelingsniveau, blijkt praktisch onhaalbaar omdat een groot aantal afdelingen of ziekenhuizen nodig is vanwege heterogeniteit in de standaardzorg, patiëntengroepen, fte ratios, expertise van de afdelingsstaf, enzovoorts. Bij het meest gebruikte alternatieve design, het quasi experiment met een historische controlegroep, ontbreekt randomisatie van de studiepopulaties. Hoewel in dit design voor heterogeniteit van de onderzoekspopulaties kan worden gecontroleerd is controle voor andere beïnvloedende factoren, zoals ontwikkelingen in de medische behandeling en organisatieveranderingen, niet mogelijk.

Aanvullend hebben we de meest gebruikte uitkomstmaten: reanimatie, overlijden, en ongeplande IC-opnames bediscussieerd. Verschillende studies laten na implementatie van een SIS een afname in het aantal reanimaties zien. Deze afname kan echter ook zijn veroorzaakt doordat na implementatie van het SIS met meer patiënten een 'niet reanimeerbeleid' wordt afgesproken. Deze mogelijkheid wordt bevestigd in een meta-analyse die een toename van het aantal patiënten met een 'niet reanimeerbeleid' en een afname van het aantal reanimaties liet zien terwijl de ziekenhuissterfte niet daalde. De studies die wel een significantie afname in ziekenhuissterfte lieten zien hadden allemaal een hoge baseline ziekenhuissterfte van 10 of meer per 1000 patiënten. Het is duidelijk dat in onze studie een afname in onverwacht overlijden, met een baseline incidentie van slechts 3,6 patiënt per 1000 opnames, bijna onmogelijk was om te bewijzen. Tot slot wordt, gebaseerd op de hypothese dat door implementatie van het SIS het aantal IC-opnames zal afnemen, in meerdere studies de uitkomstmaat: (ongeplande) IC-opnames gehanteerd. Deze uitkomstmaat is discutabel omdat ten gevolge van het SIS mogelijk meer patiënten als vitaal bedreigd worden herkend en tijdig naar de IC worden doorverwezen. Wij concludeerden dat toekomstig onderzoek zich beter kan richten op de diverse aspecten van zorg rondom de vitaal bedreigde patiënt, zoals verbetering van de signaleringssystemen en behandeling van de vitaal bedreigde patiënt. Tevens moet gewerkt worden aan de ontwikkeling van effectieve en efficiënte organisatievormen die passen bij de diverse organisatorische settings, en als laatste aan de verbetering van de implementatiestrategieën.

Ten slotte hebben we in hoofdstuk 7 de resultaten samengevat, bediscussieerd en de implicaties voor de praktijk beschreven. Wij concludeerden dat implementatiestrategieën op het gehele medische en verpleegkundige afdelingsteam gericht moeten zijn om een intensiever gebruik van het MET te realiseren. Bovendien moet formeel beleid worden gevoerd om vitaal bedreigde patiënten in een vroegere fase naar de IC te verwijzen, waardoor ze minder ziek op de IC komen en hun opnameduur op de IC korter zal zijn. Effecten van

dit beleid kunnen in kaart worden gebracht met de uitkomstmaat: 'ongeplande IC-dagen per 1000 patiënt-dagen' in combinatie met de resultaten van procesevaluaties. Met deze gegevens kan op afdelingsniveau worden besloten of een SIS een meerwaarde heeft voor effectieve en efficiënte zorg aan de vitaal bedreigde patiënt.

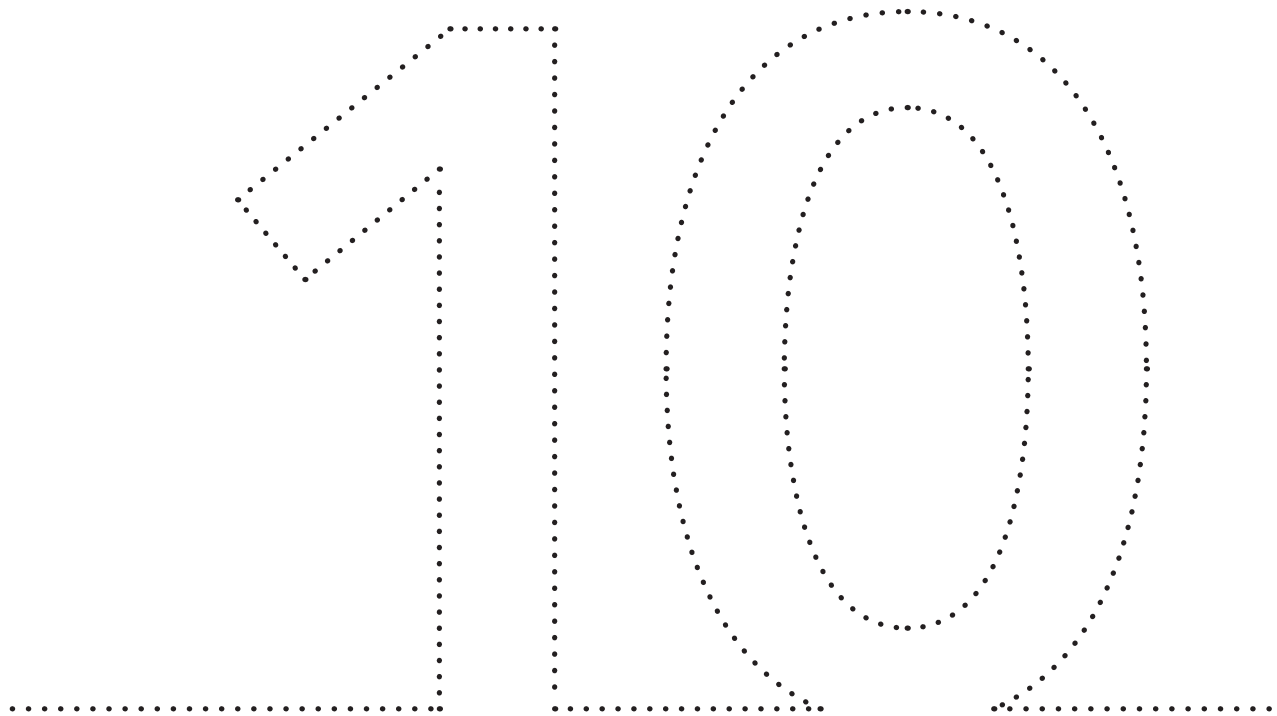
List of abbrevations



List of abbrevations

ANCOVA	Analysis of covariance
APACHE	Acute physiological assessment and chronic health evaluation
ASA-PS	American Society of Anesthesiologists - physical status
AWTTS	Aggregated weighted parameter track and trigger system
BP	Systolic blood pressure
CCO	Critical Care Outreach team
CI	Confidence Interval
DNR	Do not resuscitate
EMV	Eye, motor, verbal score
EQ-5D	EuroQol-5 dimensions
EWS	Early warning score
H	Hour
HF	Heart frequency
HRQOL	Health Related Quality of Live
ICU	Intensive Care Unit
IQR	Interquartile range
LOS	Length of stay
MET	Medical Emergency Team
O2	Oxygen saturation
OR	Odds Ratio
P1	Period 1
P2	Period 2
RCT	Randomized controlled trial
RR	Respiratory rate
RRS	Rapid Response System
RRT	Rapid response team
SAE	Serious adverse event
SD	Standard deviation
Sec	Seconds
SF-6D	Short form 6 dimensions
VAS	Visual analogue scale

Dankwoord



Dankwoord

Het is geweldig dat het spoedinterventiesysteem in het hele Radboudumc is geïmplementeerd en anderen met verve doorgaan om het spoedinterventiesysteem verder te ontwikkelen. Deze promotie is in samenwerking, en met ondersteuning van veel mensen tot stand gekomen, zonder hen was het nooit gelukt. Hiervoor wil ik iedereen van harte bedanken. Sommige mensen wil ik graag in het bijzonder noemen.

Dr. prof. Hans van der Hoeven, promotor en vooral inspirator. Ik voelde mij bevoorrecht om jou als promotor te mogen hebben. De gesprekken met jou en de overige leden van de begeleidingscommissie waren bijzonder motiverend. Je gedrevenheid en enthousiasme om goede patiëntenzorg te realiseren met oog voor de menselijke kant spraken mij aan. Ik leerde van jou om zeer 'to the point' te schrijven. Je positieve feedback heeft mij enorm geholpen om door te gaan. Hiervoor wil ik je hartelijk danken.

Dr. Lisette Schoonhoven, copromotor en mijn belangrijkste toeverlaat, in goede en slechte tijden. Je rust, je vakvrouw-schap met je kritische vragen en gerichte feedback. Jij bleef met alle geduld zaken uitleggen en gaf me kans om dingen te verbeteren. Daarnaast had je altijd tijd en belangstelling om te praten over de niet minder belangrijke zaken van het leven. Het geblaat van jouw schaap heeft menigmaal aan een fijn gesprek een onverbiddelijk einde gemaakt. Kortom, ik heb het bijzonder gewaardeerd dat jij mijn copromotor was, een baken waarop ik vertrouwde en waarop ik durfde te varen. Bedankt.

Dr. Joke Mintjes, jij was de eerste lector en oprichter van het lectoraat 'acute intensieve zorg' van de hogeschool van Arnhem en Nijmegen, en mijn copromotor. Met je enthousiasme heb je in korte tijd een geweldig netwerk voor het lectoraat tot stand gebracht en introduceerde je jouw kenniskringleden in de praktijk. Zo bracht je Ans Rensen en mij in contact met collega's in het Radboudumc en raakten wij betrokken bij 'Outreach', zoals het Spoedinterventiesysteem in het Radboudumc wordt genoemd. 'Wat wil je nu zeggen', 'maar dat staat er niet', 'schrijven is schrappen', allemaal uitspraken die ik bij herhaling van je heb gehoord. Jouw afgekloven potloodje waarmee je schema's tekende, en de, zeker in aanvang van het traject, soms verhitte gesprekken om mij te overtuigen, wat niet altijd eenvoudig was. Je niet aflatend optimisme en de complimenten als je vooruitgang zag. Voor dit alles, bedankt.

Dr. Bernard Fikkers, intensivist en lid van de begeleidingscommissie. Hoe je het voor

elkaar kreeg weet ik niet, maar iedere keer weer had je binnen de kortste keren mijn conceptstukken nagekeken en van commentaar voorzien. Je betrokkenheid was groot, je gaf mij veel suggesties om te verbeteren. Ik was wel zo eigenwijs om hier regelmatig tegenin te gaan. Dit heeft tot veel discussie geleid met verscherpte inzichten als resultaat. Schuren doet glanzen, en ik ben je gaan waarderen om je spontane, betrokken en eerlijke houding. Bedankt voor je ondersteuning.

Ans Rensen, lid van de kenniskring en collega docent, ook jou wil ik bijzonder hartelijk danken. Ans, ik weet niet hoe het zonder jou met de implementatie van 'Outreach' was afgelopen. Je vasthoudendheid om de implementatie tot een goed einde te brengen en je aandeel in het kwaliteit van leven onderzoek waren van grote waarde. Daarnaast ben je een geweldige collega, altijd een luisterend oor en je kunt met de nodige humor rake dingen te zeggen. Ik ben er trots op, en er blij mee, dat je mijn paranimf wilt zijn.

Marian Adriaansen, toenmalig afdelingsdirecteur instituut verpleegkunde studies, jij moest met jouw collega's beslissen wie van de drie sollicitanten die ene onderzoeksplaats mocht innemen. Marian, je hebt me voor de poorten van de hel weggesleept, zoals je me later vertelde. Ik had goede papieren maar mijn leeftijd was in de ogen van jouw collega's een belangrijk minpunt. Hoewel ik tijdens enkele sombere momenten wel eens dacht dat je de poorten van de hel voor mij hebt geopend, wil ik je hartelijk danken voor het vertrouwen dat je in mij hebt gesteld. Ook de HAN, in het bijzonder Frank Stöteler, toenmalig directeur van de faculteit gezondheid en maatschappelijke dienstverlening, Carolien van Mierlo, directeur, en Marijke Beckers, adjunct-directeur instituut verpleegkunde studies, bedankt voor de kansen die mij zijn geboden.

Jan Vesseur, hoofdinspecteur gezondheidszorg, jij schreef op een late avond, nadat je onze workshop over 'Outreach' had bezocht, een pleidooi om de effecten van het Spoedinterventiesysteem te onderzoeken. Jouw pleidooi kon ik op de valreep aan mijn sollicitatiepapieren voor de onderzoeksplaats toevoegen. Dit heeft er zeker toe bijgedragen dat ik de plaats heb gekregen, waarvoor hartelijk dank.

De voorbereidingen en implementatie van 'Outreach' werd door vele mensen in het ziekenhuis gedragen. Het is onmogelijk alle mensen te noemen, in het bijzonder wil ik hier noemen: Daan Sep, intensivist, Monique Bonn, IC-verpleegkundige en Gerrit Bloo, IC-verpleegkundige en onderzoeker, jullie hebben een belangrijke aanzet gegeven om 'Outreach'

te implementeren. Aan de uitwerking van het implementatieplan, de ontwikkeling van de training en de implementatie op de afdeling speelden vooral Trix Terwindt en Willy van Breemen afdelingsverpleegkundigen, Marion van der Kolk, intensivist en chirurg, Bernard Fikkers, intensivist, Maurice Peeters, afdelingshoofd, Ton Haans, nurse practioner IC, en Haico van Deyne, IC-verpleegkundige en praktijkdocent, een belangrijke rol. Jullie zorgden dat de verpleegkundigen werden geschoold en het project bij iedereen bekend raakte en jullie motiveerden collega's voor het project. Mede door jullie inspanningen heeft 'Outreach' haar weg in de ziekenhuisorganisatie gevonden.

Zonder de medewerking van patiënten hadden we geen beeld gekregen over hun ervaren kwaliteit van leven. Het was bijzonder om te zien hoe soms zeer ernstig zieke patiënten toch de vragenlijsten wilden invullen om zodoende hun steentje bij te dragen om de zorg te verbeteren. Allemaal hartelijk bedankt. Daarnaast wil ik de vele HBOV studenten bedanken die in het kader van hun kwaliteitsproject hebben meegewerkt aan de dataverzameling van het kwaliteit van leven onderzoek.

Maaike Jansen en Remco Ebben, wat was ik blij toen ik van een eenzaam kamertje in het ziekenhuis kon verhuizen naar een werkplek op het Bisschop Hamerhuis met jullie als medeonderzoekers. Elkaar iets vragen, tegenslagen delen en overwinningen vieren. Het leven werd er een stuk aangenamer op, ik voelde me bij jullie thuis. Ook Lilian Vloet wil ik hier bedanken. Je hebt het stokje van Joke overgenomen en bent nu de lector van ons lectoraat acute intensieve zorg. Je volgde altijd met belangstelling mijn promotietraject. Mede door jouw inspanningen en afgeleid van mijn onderzoek hebben we projectgelden aangevraagd en ontvangen waarmee we in samenwerking met Doczero een e-learning programma voor onze HBOV studenten hebben ontwikkeld waarin zij de gestructureerde communicatiemethode in acute situaties kunnen aanleren. Ook de associate lectoren Lisbeth Verharen en Sivera Berben en de kenniskringleden Marijke, Boukje, Ilse, Irene, Annelies, Mark, Fon, Jan, Nanda en Peter wil ik graag bedanken voor jullie belangstelling en ondersteuning. Veronica Varol, jij handelde de organisatorische rondslomp rondom het project af en dat deed je goed waardoor ik aan het werk kon blijven, hiervoor wil ik je hartelijk bedanken.

Ik heb het getroffen met mijn kamergenoten op de Kapittelweg: naast Ans, Maaike en Remco zijn dit Annegien, Ger en Sanne. Allemaal bedankt voor de gezelligheid op onze kamer. Overige collega's op de HBOV wil ik ook bedanken. Iedere dag ga ik met plezier naar mijn werk en dat is naast het contact met de studenten vooral te danken aan de goede,

collegiale sfeer in ons team.

Annick Bakker-Jacobsen Jenny Wegh, jullie hadden de ingewikkelde taak om de bijeenkomsten met de begeleidingsgroep te plannen, een heel gepuzzel gezien de agenda van de leden. Het is jullie steeds weer gelukt om een uurtje te vinden, waarvoor mijn dank. Sjef van de Velde, jou wil ik ook graag bedanken. Ik kon bij jou altijd aankloppen als ik gegevens uit het ICT systeem nodig had. Je bleef hardnekkig doorgaan met programmeren totdat de gegevens 'hapklaar' uit de computer rolden waardoor ik er meteen mee aan de slag kon. Je hebt op deze manier op een bijzonder fijne manier aan het onderzoek bijgedragen. Tevens gaat mijn dank uit naar dr. Ton de Haan en dr. George Borm, die ik kon raadplegen over statistische analyses.

Dr. Eddy Adang, biostatisticus en medeauteur van het artikel over het effect van het spoedinterventiesysteem op de ziekenhuiskosten. Je hebt een belangrijke bijdrage geleverd aan het opzetten van de scenarioanalyse waarvoor hartelijk dank.

Gerton Hermers, jou wil ik bedanken voor de prettige samenwerking. Het manuscript heeft een mooie-lay out gekregen en ik ben reuze blij met het ontwerp van de omslag.

In mijn privé zijn veel mensen die mijn leven extra glans geven en die ik hiervoor graag wil bedanken. Dat zijn de mensen in mijn straat; samen activiteiten ondernemen, elkaar helpen of even buurten maken dat ik me thuis voel in de straat en dit ervaar ik als een grote rijkdom.

Zoveel mensen die me op de één of andere manier dierbaar zijn: Hennie en Jacqueline, Els, Ellen, Marian, KupP en Jan, en natuurlijk de MGZ club: Leonie, Miek, Anja, Yvonne en José, bedankt voor jullie vriendschap. Willemijn, hier wil ik je bedanken voor de jaren dat we samen werkten en vriendinnen waren, ik heb zoveel met je gelachen en zoveel van je geleerd, jou zal ik niet vergeten.

Mijn vriendinnen Dorothé, Tineke, Marianne en Jita, we hebben veel te delen en we kunnen veel met elkaar delen. Lieve meiden, bedankt. Jacqueline, jouw humorvolle en wijze blik op het leven is een rijke aanvulling waar ik blij mee ben. Ik kijk uit naar onze pelgrimstocht.
Niet op de laatste plaats komt mijn familie, zussen en broer Tineke, Thea, Ben, Maria en hun partners, Dora en de Venhoeventjes, jullie zijn me zoveel waard. Ben bedankt voor het

meelezen. Frans, ontzettend bedankt dat jij twee weken wacht met het ophalen van jouw bul geneeskunde. Het blijft een verdrietige herinnering dat tijdens het promotietraject, terwijl ik soms in de kelder van het ziekenhuis de dossiers uitploos broer Harrie afwisselend was opgenomen op neurologie en de IC om uiteindelijk in het hospice te sterven. Siny, bedankt dat we het verdriet om Harrie met elkaar konden delen.

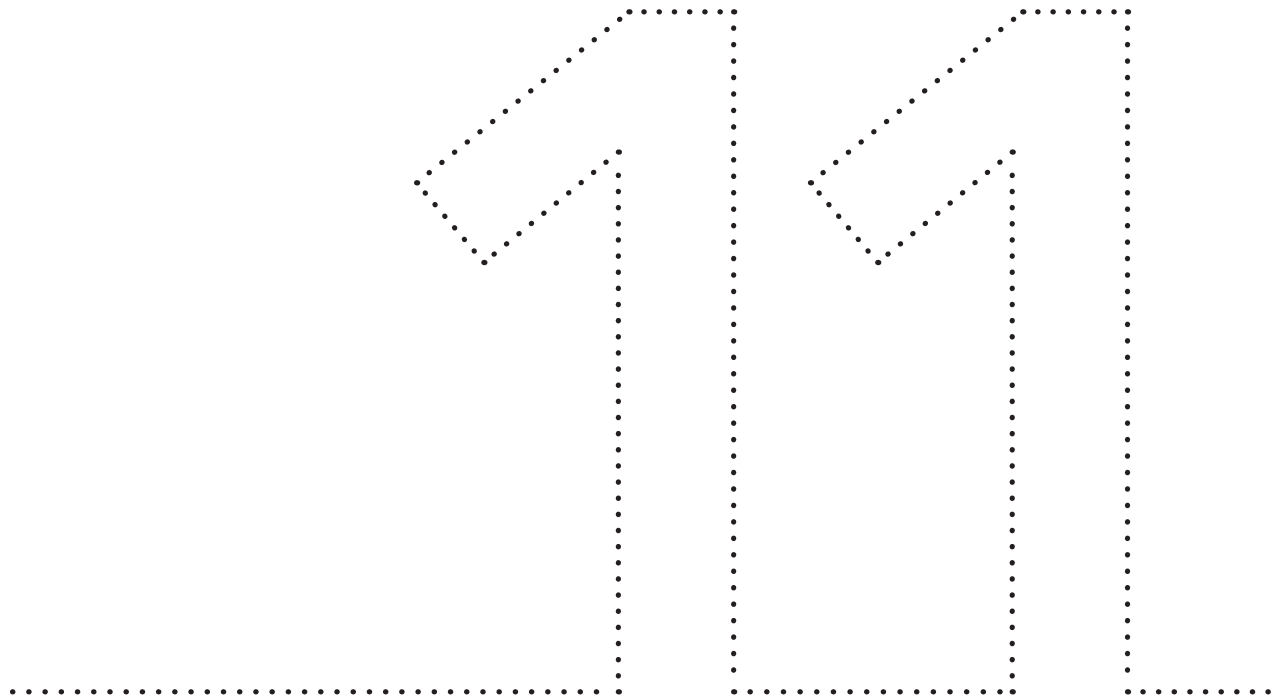
De warmte en samenhorigheid in ons gezin hebben we vooral te danken aan onze ouders die ons een solide basis hebben meegegeven waarop wij ons leven konden bouwen. Moeder met je zorg en je leuke grapjes, helaas heb ik je niet meer kunnen vertellen over dit project. Vader, jij vond het prachtig dat ik aan deze studie was begonnen. Ondanks je heupfractuur heb je het weer tot lopen gebracht. Met de geweldige hulp van je vrouw Dora heb je nog enkele jaren van het leven genoten. Vader, jouw wilskracht heb ik enorm bewonderd en ik ben je dankbaar voor het voorbeeld dat je voor mij bent geweest.

Henk, mijn overleden vriend met wie ik getrouwd was, jij bent van onschatbare waarde geweest voor mijn ontwikkeling. Jij begreep dat het voor mij belangrijk was dat ik verder wilde studeren, met alle gevolgen van dien. Op zaterdagen ging ik naar de universiteit met soms tranen in mijn ogen, want daar stond jij, met onze dochters in de hand, klaar voor een dag van vrijheid zonder moeder, waar alles mocht en kon. Later kwam dit project op mijn pad, en ik weet dat jij gezegd zou hebben dat ik het moest doen, want je geloofde in mij, vaak meer dan ik in mezelf geloofde. Het blijvend contact met schoonzussen Nel en Jenne is me dierbaar.

En natuurlijk Hanna en Teuni, onze dochters. Ik ben zo blij en gelukkig met jullie en geniet van de momenten dat we samen zijn. Alle drie bezig met een promotiestudie, dat geeft leuke discussies, over de maatschappij, het milieu, over de waarden van het leven. Jullie begrepen goed waarom ik vaak weinig tijd had en daar wil ik jullie voor bedanken. Ik hoop dat dit ik in de toekomst meer voor jullie klaar kan staan en soms een weekendje uit of een vakantie met jullie, Koos en Niels kan organiseren. Misschien dat jullie nog eens met weemoed terugdenken aan de afgelopen tijd toen jullie moeder zich amper met jullie bemoeide?

Kees, jouw bestaan geeft een bijzondere dimensie aan mijn leven. Geïnspireerd door jouw ideeën ontwikkel ik een ruimere kijk op het leven. Bij jou rust ik uit, verwerk ik ervaringen en doe ik energie op. Ik verheug me om met jou de Engelse wals te leren dansen. Lieve Kees, graag wil ik met jou, en om jou heen dansend, het leven vervolgen.

Curriculum vitae



Curriculum vitae

Friede Simmes werd op 7 april 1952 in de Noordoostelijke polder geboren. Na de huishoudschool, assistenteklas, en opleiding tot inrichtingsassistente volgde zij van 1969-1973 de in-service opleiding Verpleegkundige A, in het St. Josef ziekenhuis te Deventer. Van 1973-1974 was zij werkzaam als praktijkbegeleidster in het St. Josef ziekenhuis en haalde zij haar Avondmavo-4 diploma. Zij startte in 1975 de tweejarige opleiding in de 'algemene maatschappelijke gezondheidszorg'. Zij werkte daarna als wijkverpleegkundige in het gezondheidscentrum de Hazenkamp in Nijmegen en als verpleegkundige in het Kinderdorp Neerbosch te Nijmegen. Van 1979-1981 volgde ze de hogere opleiding voor verpleegkundigen, daarna was ze tot 1987 werkzaam als hoofdwijkverpleegkundige bij de Regionale Vereniging het Groene Kruis Noord Limburg. Daarnaast volgde ze van 1986-1987 de deeltijdopleiding 'tweede fase hoger sociaal en agogisch onderwijs' en behaalde ze haar eerste graads onderwijsbevoegdheid.

Vanaf 1988 tot heden is Friede werkzaam als (hoofd)docent aan het instituut verpleegkunde studies van de Hogeschool van Arnhem en Nijmegen (HAN). Van 1994 tot 1998 studeerde zij gezondheidswetenschappen, richting verplegingswetenschap, aan de Universiteit Maastricht. In 2005 werd Friede aangenomen als lid van de kenniskring acute intensieve zorg van de HAN en sindsdien combineert ze haar functie als hoofddocent met een de functie van onderzoeker. Binnen het onderwijs is Friede vooral betrokken bij de ontwikkeling, organisatie en uitvoering van de 'onderzoeksleerlijn' van de HBOV. In de functie van onderzoeker werd Friede in 2006 betrokken bij de ontwikkeling van het 'Outreach' implementatieplan. in 2008 kreeg ze van de HAN een promotieplaats om de effecten van 'Outreach' te onderzoeken. Sinds 2014 is zij projectleider van het onderzoek naar familiegericht zelfmanagement.

Friede kreeg samen met Henk ten Brink twee dochters, Hanna (1986) en Teuni (1988). Henk overleed in 1981. Friede woont in Escharen. Haar vriend Kees Bisseling woont in Saint Germain d'Esteuille, Frankrijk.